SOCIOECONOMIC DISADVANTAGE AND COGNITIVE FUNCTION ACROSS THE LIFE SPAN: TRENDS AND UNDERLYING MECHANISMS

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ABSTRACT

Kristen Schorpp: Socioeconomic Disadvantage and Cognitive Function across the Life Span: Trends and Underlying Mechanisms
(Under the direction of Yang Claire Yang and Kathleen Mullan Harris)

During the past several decades, the United States has seen rising socioeconomic inequality coupled with an aging population and rising morbidity. Given these trends, a better understanding of how socioeconomic inequalities contribute to health among older adults is needed. Cognitive function, defined by the ability to learn, recall, and manipulate knowledge, is especially important for individual health, wellbeing, and independence in late life. However, the life course links between socioeconomic conditions and cognitive outcomes remain poorly understood for several reasons. First, the aging literature typically focuses on the links between adult socioeconomic conditions and late life cognitive function; however, the experience of socioeconomic disadvantage in early life may be especially detrimental to cognitive aging by setting individuals on social, psychological, and physiological trajectories that influence the aging process. Second, the links between socioeconomic status and cognitive function are not necessarily direct, but may be conditioned by broader social and economic contexts, as well as individual differences that shape responses to the experience of disadvantage.

To fill these research gaps, my dissertation utilizes three national, longitudinal data sources that capture adolescence and young, mid, and late adulthood to identify the associations of life course socioeconomic disadvantage with cognitive function across the life course. In addition, I examine historical, contextual, and individual factors that modify the links between

socioeconomic conditions and cognition. Chapter two tests the interactive associations of household, school, and neighborhood socioeconomic conditions for young adult memory function. Chapter three tests the moderating effect of personality on the association of childhood socioeconomic disadvantage with midlife cognitive function. Finally, chapter four examines cohort differences in the links between life course socioeconomic disadvantage and cognitive function and decline. Collectively, these examinations find that socioeconomic conditions across childhood, adolescence, and adulthood are significantly associated with adult cognitive outcomes, and that contextual, historical, and individual factors modify these links.

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CHAPTER ONE: AN INTRODUCTION TO SOCIOECONOMIC INEQUALITIES IN COGNITIVE FUNCTION

In a statement issued by the National Institutes of Health titled "Preventing Alzheimer's Disease and Cognitive Decline," adult cognitive decline and dementia were characterized as "major causes of morbidity and mortality worldwide that are substantially burdensome to the affected persons, their caregivers, and society in general" (Daviglus et al. 2010). Epidemiological literature supports these assertions: a recent study estimated that 5.4 million people over age 71 have mild cognitive impairment without dementia in the U.S., and among those with mild impairment, 11.7% progress into dementia annually (Plassman et al. 2008). Further, medical care for an individual with dementia cost an average of $42,000-$56,000 in 2010, making the total economic burden of dementia in the U.S. between 157 and 215 billion dollars for that year (Hurd et al. 2013). These figures are especially troubling given Census projections of the shifting U.S. age structure as the Baby Boom cohort enters older adulthood, which is expected to put further strain on health care systems (U.S. Census Bureau 2014). Therefore, identifying the complex determinants of cognitive functioning and decline in late adulthood is crucial to improving the cognitive health of older adults and minimizing health care expenditures.

Studies using older samples have provided evidence for the social contributors to cognitive outcomes (e.g., Bassuk, Glass, & Berkman 1999; Barnes et al. 2004; Evans et al. 1997; Luo & Waite 2005), but most research has neglected to examine the social determinants of cognitive function and decline that occur in all stages of the life course, including childhood and adolescence, young adulthood, and the middle to late adult years. Indeed, cognitive delays that occur in childhood have negative consequences on future attainment, health, cognitive wellbeing, and even mortality, underscoring the need to incorporate early life determinants and measures of cognition into studies of cognitive aging and overall health (Batty et al. 2005; Hatch et al. 2007; Kuh et al. 2004). In order to develop effective prevention strategies, researchers must conceptualize cognitive functioning as a life-long process shaped by social, behavioral, psychological, and physiological influences that operate additively and interactively across the life span (Baltes 1987). Such an approach to the study of cognitive function will not only elucidate the complex determinants of cognitive outcomes, but will also illuminate possible points of intervention that precede the emergence of cognitive decline.

A growing literature has identified socioeconomic disparities in cognitive function in both childhood and late adulthood. In childhood and adolescence, SES is significantly associated with early life working memory and cognitive ability (Evans & Schamberg 2009; Guo 1998; Noble et al. 2007), and by late adulthood, those in disadvantaged socioeconomic positions are at greater risk of cognitive impairment and dementia (Cagney & Lauderdale 2002; Luo & Waite 2005; Lynch et al. 1997). While these studies shed light on the link between SES and cognitive function, the NIH states that the magnitude of this linkage across the life span and the underlying mechanisms that explain it remain inconclusive (Daviglus et al. 2010), motivating a deeper assessment of the relationship between SES and cognitive function across the life span.

Utilizing several U.S. data sources, the goal of my dissertation is to examine how multidimensional and longitudinal dynamics of socioeconomic disadvantage affect cognitive function across young, mid, and late adulthood. Further, I consider sources of variation in the link between disadvantage and cognitive outcomes. Specifically, I examine whether broader socioeconomic contexts, individual personality characteristics, and historical time modify the influences of individual SES on cognitive function. This approach is aligned with the life course framework, posits that individual actors are embedded within institutional and historical forces that shape life trajectories (Elder 1998; Elder, Johnson, & Crosnoe 2003).

My dissertation is organized into five chapters. These consist of the introduction in chapter one, three empirical papers presented in chapters two through four, and the conclusion in chapter five. Chapter one provides an overview of the research questions, the relevant literature and theoretical framework used to guide analyses, data sources, and the proposed relevance of this research for public health and contributions to the field.

Conceptual Approach and Guiding Theoretical Frameworks

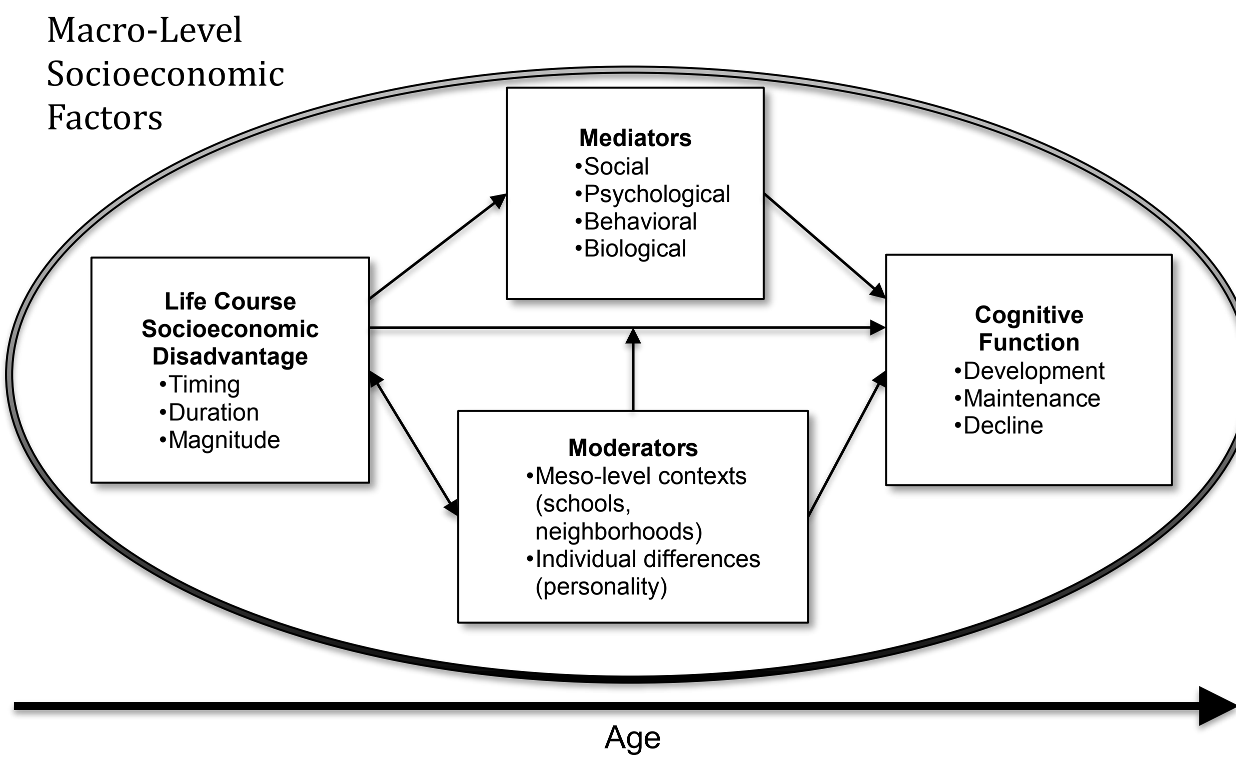

Figure 1-1: *Socioeconomic Disadvantage and Cognitive Function across the Life Span*

The conceptual approach for my dissertation research is illustrated in Figure 1-1. My work draws from the life course perspective, which underscores the longitudinal dynamics between socioeconomic status and cognition, as well as the capacity for contextual- and individual-level factors to explain or modify these dynamics. Below, I describe the guiding theoretical frameworks for the conceptualization and measurement of 1) socioeconomic disadvantage, 2) cognitive function, and 3) mediating mechanisms, as well as how we can draw linkages between these concepts.

Socioeconomic Status and Cognitive Function across the Life Span

While socioeconomic disparities in cognitive function have been identified in the literature, less is known about how the impacts of SES, particularly socioeconomic disadvantage, unfold across early life, young adulthood, midlife, and old age. Applying a longitudinal, life course framework to the relationship between SES and cognitive function will shed light on the socioeconomic contributors to cognitive development and decline. The life course framework posits that the timing and succession of social roles and circumstances experienced across time shapes life chances across social, economic, psychological, and health domains (Elder 1998; Elder & Shanahan 2006). In addition, the life course framework considers the interplay of factors across macro-, meso-, and micro-levels, such as broader historical contexts, school and neighborhood conditions, and individual characteristics, in shaping life trajectories (Elder, Johnson, & Crosnoe 2003).

As shown in Figure 1-1, my work examines how the timing, duration, and magnitude of socioeconomic disadvantage across the life span is tied to cognitive outcomes. I incorporate multidimensional socioeconomic measures that span early life and adulthood in order to understand how early life disadvantage shapes long-term cognitive trajectories. Several longitudinal models have been used in the health literature to describe the specific influences of timing, duration, and magnitude of socioeconomic disadvantage on cognitive outcomes. These models include 1) the sensitive periods model, which posits that the effects of SES on health are restricted to developmental windows of sensitivity; 2) the cumulative model, which emphasizes the role of persistent advantage or disadvantage over time in affecting health; 3) the pathway model, which argues that early life SES shapes adult health through its impact of early life SES on adult SES; and 4) the mobility model, which places emphasis on the impacts of *change* in socioeconomic conditions on health outcomes (Hallqvist et al. 2004; Loucks et al. 2010; Luo & Waite 2005). Each of these models captures unique impacts of timing and duration of socioeconomic conditions across the life span; for example, while the sensitive periods model emphasizes how the *timing* of early life disadvantage has unique impacts on adult outcomes, the cumulative, pathway, and mobility models are more concerned with how *duration* and *change* in disadvantage across time shape later outcomes. These models have been explored in relation to physical and mental health outcomes, including cardiovascular disease (Hallqvist et al. 2004), inflammation (Loucks et al. 2010), and depression (Luo & Waite 2005). Preliminary research has also explored how these life course models relate to cognition in older adults, and has found evidence for cumulative impacts of early life and adult SES on cognition (Luo & Waite 2005), suggesting that SES across all life stages is important for cognitive outcomes. Further research should examine how the linkages between SES and cognition unfold across multiple life stages.

In addition to considering these longitudinal models, my research examines historical, contextual, and individual factors that potentially drive variation in the associations between life course socioeconomic disadvantage and adult cognitive outcomes. This is shown in the "Moderators" component of the conceptual model in Figure 1-1. While evidence implicates socioeconomic disadvantage as a significant predictor of cognitive function, these the significance and magnitude of these associations differ across individuals. A number of factors could alter an individual's vulnerability to negative impacts of socioeconomic disadvantage, especially during the formative years in childhood and adolescence. For example, some might be more vulnerable to the negative impacts of socioeconomic disadvantage than others depending on macro-level social conditions that define opportunity structures (such as educational incentives, economic recessions, and wars), the availability or deprivation of resources in surrounding contexts (such as in neighborhoods or schools), or personality characteristics that affect risk and resilience in disadvantaged settings (such as neuroticism or conscientiousness). Consideration of the multilevel contributors to cognitive outcomes and how they interact with individual socioeconomic status offers a more complex and comprehensive view of the social determinants of cognitive function that aligns with the life course perspective.

Cognitive Function across the Life Span

In addition to conceptualizing SES as a longitudinal construct, it is important to capture cognitive function as a dynamic and multidimensional outcome. Cognition encompasses many functional domains, including attention, working memory, episodic memory, perception, reasoning, language, and executive control (Glisky 2007). However, these cognitive processes are not independent of one another, but rather are often applied in tandem for any given task. For example, completing a working memory task generally requires the ability to pay attention to the task at hand, recall information (episodic memory), and manipulate this information to develop a solution (thus relying on reasoning, inhibitory control, and executive control) (Gilsky 2007). Further, cognitive function is not a fixed characteristic across the life span, but rather follows a general pattern of early life development, midlife maintenance, and late life decline. Therefore, we can also explore 1) how socioeconomic conditions are differentially related to cognitive function across each life stage, and 2) how socioeconomic conditions affect *change* in cognitive function (that is, development, maintenance, and decline) within early life, midlife, and late adulthood, respectively. Exploration of these research questions requires conceptualization of both socioeconomic conditions and cognitive function as longitudinal constructs across the life span; however, studies that examine the links between socioeconomic status and cognitive function are often limited to samples of older adults because this is when cognitive function and impairment becomes the most clinically relevant. I argue that in order to understand processes of cognitive decline in late life, we also need to examine trajectories of cognitive functioning and its determinants at earlier stages of the life span.

First, aligned with Figure 1-1, measures of cognitive change within data sources will help to elucidate how socioeconomic conditions relate to development, maintenance, and decline of cognitive function within early life, midlife, and late adulthood, respectively. While rates of development and decline are likely contingent upon life course patterns of socioeconomic conditions, cognitive change is rarely assessed in studies of social conditions and cognitive outcomes. Such investigations, however, could reveal how cognitive decline and transitions into dementia are socioeconomically patterned, with cognitive changes that occur long before clinical significance.

Second, comparison of results from each chapter, which address cognitive outcomes at different life stages, will allow me to draw inferences regarding how longitudinal socioeconomic conditions are associated with cognitive function across young, mid, and late adulthood. In other words, comparison across data sources that represent different age groups can help to determine whether early life disadvantage remains a significant, independent predictor of cognitive function from young adulthood to midlife to late adulthood, or instead, whether these associations fade by older age. This approach takes a step beyond testing the life course models within data sources, and provides an opportunity to observe how these longitudinal associations unfold across adulthood.

Mechanisms of Socioeconomic Disparities in Cognitive Outcomes

Studies to date have neglected to thoroughly examine *how* disadvantage affects cognitive function. The stress process model provides a useful framework to understand socioeconomic disparities in cognition by illuminating the social structural roots of inequalities in stressor exposure (including more acute stressful life events as well as chronic life strains), mediators of stress (such as social supports or coping behaviors), and stress outcomes or manifestations (such as psychological distress, depression, and physical health) (Pearlin 1989; Aneshensel 1992). Aligned with the stress process model, theories of differential exposure and vulnerability assert that people in disadvantaged social contexts are disproportionately more likely to be exposed to stressors and also less likely to have the social resources to cope with these stressors, thus affecting their health and wellbeing (Kessler 1979; Aneshensel 1992). Such theoretical approaches frame socioeconomic status as a fundamental determinant of both stressor exposure and the availability of resources to manage stress, and have been widely used to explore the multiple social, psychological, behavioral, and even physiological mechanisms that explain how stress affects physical and mental health outcomes.

Explorations of the influence of social stress on cognition are limited. Several studies have found that differential exposure to stress contributes to socioeconomic gradients in both child and adult cognitive functioning (e.g., Noble et al. 2005; Evans & Schamberg 2009), warranting further exploration of stress-related processes that potentially mediate the link between SES and cognitive function. These stress-related processes include 1) differential exposure to acute or chronic stressors, 2) differential availability of social support, 3) socioeconomic disparities in health-risk or protective behaviors, 4) differential experience of psychological distress or depression related to stress exposure, and 5) disparities in underlying physiological processes related to stress as a result of differential stressor exposure. The planned studies described in the following chapters will test for the stress-related mechanisms that are available in each data source. These measures include (in order of "Mechanisms" shown in Figure 1-1) 1) perceived stress and stressful life events, 2) Berkman's social integration index (Berkman & Syme 1979) and perceptions of social support and strain, 3) body mass index, cigarette smoking, and physical activity, 4) depressive symptoms, diagnosis of depression or other psychiatric conditions, and 5) physiological measures of sympathetic nervous system activation, inflammation, and cardiovascular functioning.

Testing underlying mechanisms is also important for understanding why historical, contextual, or personality characteristics might alter the links between socioeconomic disadvantage and cognitive function. From a stress process perspective, social contexts or personality traits could affect stress exposure, coping, and ultimately cognitive outcomes. For example, greater neighborhood or school social support might enable better stress coping among youth from disadvantaged households, thus protecting against the negative impacts of disadvantage on cognitive outcomes. Further, personality characteristics could influence perceptions of stressors and stress coping behaviors. While higher neuroticism is likely to magnify the experience of stress and increase engagement in risk behaviors, conscientiousness could lead to more proactive avoidance of stressors and greater help-seeking behaviors that mitigate the negative impacts of stress. These are just a couple of ways in which social and individual factors might operate to modify the impacts of socioeconomic disadvantage on cognition.

Research Questions by Chapter

This research examines socioeconomic disparities in cognitive development and decline across the life span, as well as the ways in which historical, contextual, and individual factors modify the links between disadvantage and cognitive outcomes. Each of my empirical chapters draws from my primary conceptual model in Figure 1-1 to test specific aspects of the links between socioeconomic disadvantage and cognitive outcomes at different stages of the life span. Specifically, I examine (in order of dissertation chapter): 1) the ways in which school and neighborhood socioeconomic contexts modify the link between adolescent household disadvantage and young adult memory function; 2) associations of childhood socioeconomic disadvantage with midlife cognitive function, as well as the moderating effect of protective personality traits; and 3) cohort differences in the associations of life course socioeconomic disadvantage with late life age trajectories of cognitive decline. In addition, for all chapters, I test the social, psychological, behavioral, and physiological processes that potentially underlie these associations. A more detailed overview of the research questions by chapter is provided below.

Chapter Two. *Does exposure to affluent school and neighborhood contexts in adolescence modify the longitudinal association between household socioeconomic disadvantage and young adult memory function? If so, what are the social, psychological, behavioral, and physiological mechanisms that explain these associations?*

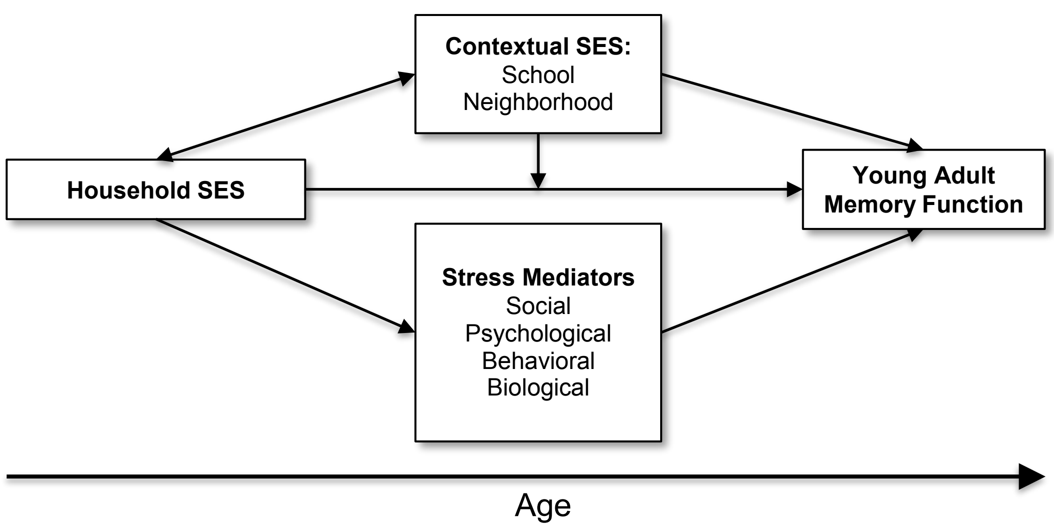

Figure 1-2: *Trajectories of Early Life SES and Young Adult Memory Function*

Figure 1-2 shows the conceptual model for chapter 2. While extensive research has provided evidence that early life SES, particularly disadvantage, is tied to late life cognitive decline, the impacts of dynamic early life socioeconomic trajectories on young adult memory have not been examined, which would provide evidence for social disparities in cognitive functioning long before the emergence of age-related cognitive impairments and dementia. Given that working memory in young adulthood and midlife is predictive of cognitive decline in late adulthood (Hernandez et al. 2013), identification of socioeconomic factors that predict memory function in young adulthood has important implications for preventative interventions. Further, utilizing a multilevel approach to examine household, school, and neighborhood level associations will provide a more comprehensive view of early life socioeconomic contributors to cognitive outcomes.

I test two competing hypotheses regarding the moderating effects of school and neighborhood affluence on the association between adolescent household disadvantage and young adult cognitive function. First, the *resource substitution hypothesis* posits that attending an affluent school or residing in an affluent neighborhood compensates for the lack of social and academic resources in a disadvantaged household, thus closing SES gaps in cognitive function. On the other hand, the *resource multiplication hypothesis* argues that those from more advantaged households will be better able to access and utilize resources in schools and neighborhoods while disadvantaged youth will not, thus widening SES gaps in cognitive outcomes. These hypotheses have been used to better understand sex gaps in returns to education (Ross & Mirowsky 2006; Ross & Mirowsky 2010), but have not been applied to the examination of cognitive inequalities.

Chapter Three. *Does personality (particularly conscientiousness) modify the links between early life socioeconomic disadvantage and midlife cognitive function? If so, what social, psychological, and behavioral processes explain these associations?*

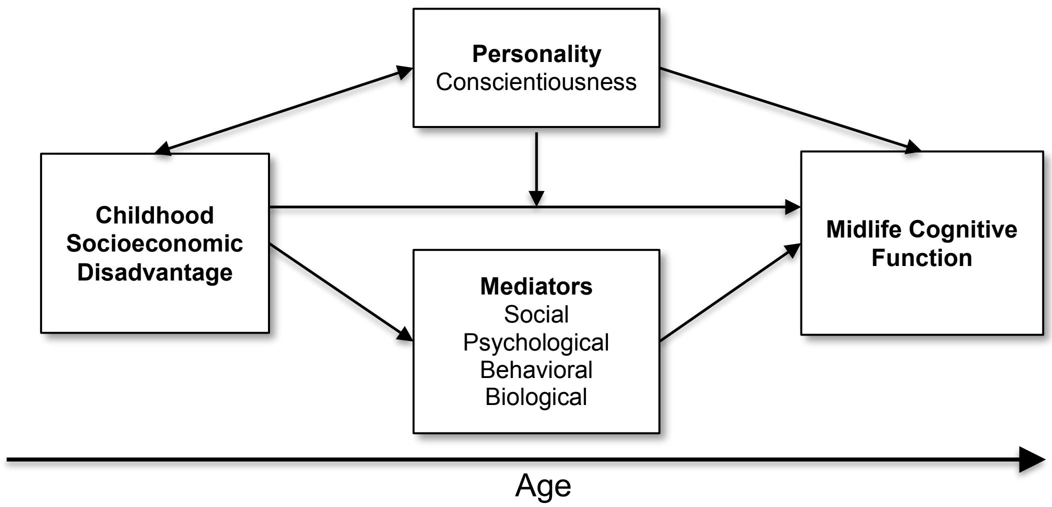

Figure 1-3: *Early Life SES, Conscientiousness, and Midlife Cognitive Function*

Figure 1-3 shows the conceptual model for chapter 3. The potential for personality characteristics to modify the influence of social conditions on physical and cognitive health is rarely examined in sociology. However, personality is important to consider because it affects the ways in which individuals interpret and respond to social conditions (Shanahan et al. 2014). Drawing from a Life Course Personality Model (Shanahan et al. 2014, I test whether conscientiousness protects against the negative impact of early life socioeconomic disadvantage on adult cognitive function. I also test whether the interactive effect of early life disadvantage on conscientiousness varies by age, as conscientiousness might be most important for middle adult cognitive outcomes and then fade with age, be equally important across the life span, or be most important in late life, when cognitive function is at greatest risk of declining.

Chapter Four. *Do associations of life course socioeconomic disadvantage with late adult cognitive function and trajectories of cognitive decline vary across birth cohorts? If so, what social, psychological, and behavioral processes explain these socioeconomic disparities?*

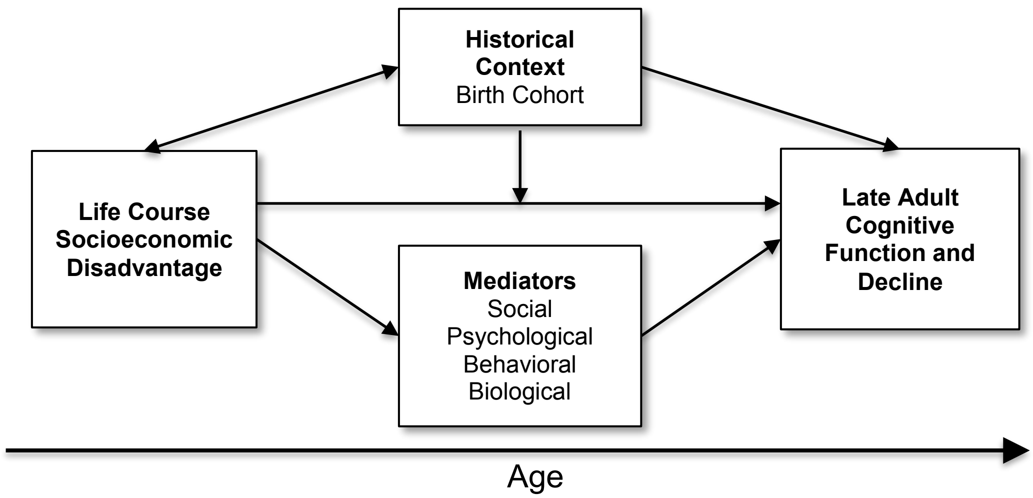

Figure 1-4: *Life Course SES, Cohort Membership, and Late Adult Cognitive Function and Decline*

Figure 1-4 shows the conceptual model for chapter 4. Building on the life course principle that individual life trajectories are embedded within historical time and place (Elder 1998), this chapter tests whether associations between life course socioeconomic disadvantage and cognitive outcomes vary across five birth cohorts born from the early 1900s to 1969. Different birth cohorts across the 20^{th} century experienced unique macro-level social and economic contexts that likely influenced individual educational, occupational, familial, and health trajectories. These macro-level influences include economic events such as the Great Depression and Great Recession, national improvements in educational resources and attainment, and World War II. Aligned with the life course perspective, the timing of exposure to these events and trends could greatly shape the influence they have on life trajectories (Elder 1998). For example, exposure to the deprivation of the Great Depression could have very different implications for cognitive trajectories if experienced during childhood compared to late adulthood. Understanding how different cohorts vary in the links between socioeconomic disadvantage and cognitive outcomes sheds light on the ways in which cognitive health is not only shaped by individual-level factors, but also by the broader social conditions in which these individual experiences are embedded.

Data Sources

To conduct a life course examination of SES, physiology, and cognitive function, this research will use several rich data sources that tap into the relevant socioeconomic factors and underlying social, psychological, behavioral, and biological processes within particular life stages. Each data source also provides unique strengths to the analysis, as described below.

Adolescent transitions into young adulthood were examined using the National Longitudinal Study of Adolescent to Adult Health (Add Health; 1994-2009), a nationally representative, school-based sample of 20,745 adolescents (Harris 2013). Respondents were age 12-18 years during the initial interview, with three follow-up interviews conducted within the subsequent 15 years. The primary strength of the Add Health data for this analysis is the available measures of household, school, and neighborhood socioeconomic conditions, which allow for a multilevel assessment of the socioeconomic contributors to cognitive function. In addition, my analysis incorporates available measures of social, psychological, behavioral, and physiological data across adolescence and adulthood to tap into possible mechanisms. More information about Add Health can be found at: http://www.cpc.unc.edu/projects/addhealth.

Mid adulthood was examined using the National Survey of Midlife Development in the U.S. (MIDUS; 1995-2006), a national sample of 7,108 adults age 25-74 at baseline. Follow up assessments were administered 10 years after the initial data collection. In both waves of MIDUS, respondents completed surveys that covered socioeconomic, psychosocial, and behavioral factors, as well as retrospective accounts of early life conditions. In addition, a subset of respondents completed a series of cognitive tests during follow up assessments that include measures of episodic memory, working memory, and executive function. More information about the MIDUS study can be found at: http://midus.wisc.edu/.

Late adult trajectories of cognitive decline were assessed using the Health and Retirement Study (HRS), a longitudinal, nationally representative sample of US adults aged 50 and older. Initial interviews of respondents and spouses took place from 1992-1993, with follow up interviews on alternating years until 2012. Additional cohorts were introduced to the original HRS sample in 1998, 2004, and 2010, bringing the total sample size to more than 26,000 adults. HRS is of particular interest for this investigation because of the multiple waves of available socioeconomic and cognitive function measures, allowing for a rich longitudinal analysis of socioeconomic disadvantage and cognitive change across late adulthood. HRS also includes data on five different birth cohorts born between the early 1900s and the late 1960s, thus providing rich data to test for cohort differences. Measures of interest for this study include retrospective measures of early life SES; multidimensional and longitudinal measures of adult SES and cognitive function; and social, psychological, and behavioral factors across late life. More information about HRS can be found at: http://hrsonline.isr.umich.edu/.

Significance and Contribution

Cognitive function is a crucial component of health with important implications for the wellbeing of individuals, the implementation of public policies, and national health care utilization and expenditures. Therefore, identifying the social contributors to cognitive function and decline has the potential to guide social interventions that spare both individuals and public health systems from the burden of poor cognitive health. In addition, a life course perspective that ties early life experiences to life-long cognitive outcomes shifts the focus from disease management to prevention – in other words, if we can identify early life predictors of later cognitive outcomes, then intervening on early life factors has the potential to prevent the emergence of cognitive decline and dementia. Finally, this work contributes to the scholarly literature identifying the social determinants of cognitive function by introducing more complex conceptualizations of socioeconomic inequalities in cognition. Incorporation of historical, contextual, and individual processes that collectively shape cognitive outcomes allows for a more comprehensive understanding of the multilevel components that interactively shape cognitive outcomes. This perspective aligns with the life course perspective and more realistically depicts the multifaceted determinants of complex health outcomes such as cognitive function

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CHAPTER TWO: MULTIPLICATIVE ASSOCIATIONS OF ADOLESCENT HOUSEHOLD, SCHOOL, AND NEIGHBORHOOD SOCIOECONOMIC CONDITIONS WITH YOUNG ADULT WORKING MEMORY

Abstract

A wide literature documents the detrimental impacts of early life socioeconomic disadvantage in the household on impairments in early life and adult cognitive outcomes; however, the role of school and neighborhood socioeconomic conditions in mitigating or widening these socioeconomic disparities remains unknown. Using the National Longitudinal Study of Adolescent to Adult Health, I test how the association of adolescent household socioeconomic disadvantage with adult cognitive function differs depending on surrounding school and neighborhood socioeconomic composition. Contact with more affluent schools and neighborhoods has the potential to compensate for household disadvantage to improve long-term cognitive outcomes. In contrast, more affluent schools or neighborhoods might only benefit higher-SES adolescents, while disadvantaged adolescents are not able to access the same benefits. I find that adolescents from higher income households scored the highest on the young adult memory tasks when from affluent schools or neighborhoods, while the cognitive scores of respondents from low-income households did not differ based on school or neighborhood affluence. Further, income differences in memory function among those from affluent contexts were partially explained by adult status attainment, adult health behaviors, and baseline cognitive ability in adolescence. Results illuminate the multiplicative influences of adolescent socioeconomic conditions across contexts for adult memory function.

Introduction

According to the U.S. Census Bureau, 21.1 percent of children under age 18 lived in poverty in 2014, an increase of 3.3 percent compared to ten years prior (DeNavas-Walt & Proctor 2015). In addition, 44 percent of children lived in households classified as low income in 2014 (Jiang et al. 2016). This has significant implications for child and adolescent cognitive development, as a growing literature across educational, developmental, and cognitive fields of research documents the importance of early life socioeconomic status in the development of working memory, verbal skills, and numeracy (Evans & Schamberg 2009; Guo 1998; Noble, McCandliss, & Farah 2007; Mercy & Steelman 1982). While children and adolescents in more affluent households tend to have the optimal resources to develop these cognitive skills and abilities, those in disadvantaged households are at greater risk of cognitive delays and lower cognitive ability due to increased exposure to stress and limited access to social, educational, and material resources (McLoyd 1998; Najman et al. 2004).

In addition to the effects of household conditions, studies find evidence for direct associations of school and neighborhood conditions with cognitive function (Dupéré et al. 2010; Rutter 1985; Rumberger & Palardy 2005; Caughy & O'Campo 2006), implicating surrounding social contexts as independent contributors to cognitive outcomes. While these studies identify the independent associations of school and neighborhood conditions with child and adolescent cognitive function, such research on contextual effects often assumes an additive model to examine the compounding influence of affluence or disadvantage across household, school, and neighborhood contexts. It remains unknown, however, whether socioeconomic resources in schools and neighborhoods have the potential to modify the impacts of household socioeconomic disadvantage on cognitive function. Two competing theoretical perspectives hypothesize the ways in which school and neighborhood affluence could modify the association of household socioeconomic conditions with cognitive function. First, access to more extensive social and economic resources available in affluent schools or neighborhoods might benefits those of a lower socioeconomic standing, ultimately enabling healthy cognitive development despite exposure to disadvantage in the household. In contrast, those from socioeconomically disadvantaged households might be unable to access resources available within more affluent contexts, while those in middle- to higher- SES households reap the benefits of these resource-rich environments. In other words, the absence of resources within the home could reduce the accessibility or value of the resources in schools or neighborhoods, while the presence of household resources enables access to resources across multiple contexts. These hypotheses have not been tested as processes related to adolescent socioeconomic contexts and young adult cognitive outcomes.

In addition, the potential for these early life conditions to have a lasting impact on cognitive function as individuals enter adulthood remains unclear. Much of the work investigating the role of household and broader contextual conditions in shaping cognitive outcomes focuses on early life cognitive development (Caughy & O'Campo 2006; McCulloch & Joshi 2001; Najman et al. 2004) or late life cognitive decline (Cagney & Lauderdale 2002; Luo & Waite 2005). However, little is known about whether adolescent socioeconomic conditions have a lasting impact on young adult cognitive outcomes. A focus on the linkage between adolescent conditions and young adult cognition may be particularly relevant for several reasons. First, adolescence is often conceptualized as a sensitive period for social and cognitive development (Ben-Shlomo & Kuh 2004; Steinberg 2005), meaning that exposure to socioeconomic conditions during this stage of development is likely to have a lasting impact on cognitive outcomes. Further, a focus on young adult cognitive function will provide insight into early life impacts on cognitive function long before the emergence of clinical cognitive impairments or decline in late life. Finally, young adult cognitive function may be especially important in shaping social and economic trajectories including transitioning into the workforce and early career development, and is therefore an important midpoint in examining long-term effects of early life experiences on cognitive trajectories.

To close these research gaps, the present study tests the moderating effects of early life school and neighborhood affluence on the association between household disadvantage and young adult working memory. Working memory is an integral component of cognitive function that is predictive of intelligence and overall cognitive ability (Baddeley 1992), and evidence also suggests that working memory is significantly shaped by socioeconomic background (Evans & Schamberg 2009; Farah et al. 2006). Using young adult working memory as an outcome, test for the interactions of household disadvantage with school and neighborhood affluence to determine whether disadvantaged youth residing in affluent communities are able to benefit from surrounding school and neighborhood resources. In other words, does affluence in schools or neighborhoods compensate for household disadvantage by boosting long-term memory outcomes among low-SES adolescents, or do only higher-SES adolescents reap the benefits of school and neighborhood affluence to improve later memory function? In addition, building on health disparities literature that implicates resource- and stress-related processes as mechanisms that underlie socioeconomic disparities in cognitive function (Lupien et al. 2001; Lynch et al. 1997), I test for social, psychological, behavioral, and physiological factors that might explain how different combinations of socioeconomic conditions across social settings ultimately affect cognition. This longitudinal and multilevel approach considers the dominant social contexts in which adolescents live and develop across the transition to adulthood, while also exploring the mechanisms through which experiences across these contexts affect cognitive outcomes.

Early Life Trajectories of Socioeconomic Disadvantage and Cognitive Function

Household socioeconomic status in childhood is a key predictor of childhood cognitive development, academic achievement, and eventual educational and occupational attainment (Bradley & Corwyn 2002; Entwisle 1997; McLoyd 1998; Sirin 2005). A number of studies document that children and adolescents from more disadvantaged households have limited access to material and social resources, including fewer cognitively stimulating materials in the household, lower parental support, and less parental investment in education relative to those in more affluent households (McLoyd 1998; Bornstein & Bradley 2014; Evans et al. 2012). In addition to the stress of material deprivation, children and adolescents in lower SES households are more often exposed to other significant stressors in the household, such as family instability and more disruptive home environments (Lupien et al. 2001; Evans & Kim 2013).

While the link between early life socioeconomic conditions and cognitive function has been identified in the literature, the linkages of adolescent socioeconomic conditions with young adult cognitive function have not been tested, though adolescence has been recognized as a particularly important life stage for social and cognitive development. Studies across psychology and developmental neuroscience identify adolescence as a sensitive period for the development of neurological structures involved in learning, memory, and reasoning skills (Fuhrmann, Knoll, & Blakemore 2015; Steinberg 2005; Knudsen 2004). Adolescence is also a time of increased social sensitivity, as teenagers increasingly spend time with peer groups in schools and the surrounding neighborhood (Cotterell 2013). These combined developmental processes across neurological and social domains make adolescence a unique life stage in which contextual influences may have a lasting impact on cognitive outcomes.

In addition to the importance of adolescent contexts for the emergence of cognitive inequalities, young adulthood is an important life stage for identification of the lasting impacts of socioeconomic conditions on cognitive function. Cognitive function in young adulthood is predictive of cognitive ability across the life span (Jefferson et al. 2011), and may also be an important indicator of cognitive decline long before its clinical emergence in late life (Deary et al. 2004). Young adult cognitive function is also important for socioeconomic trajectories across the life span by providing individuals with cognitive resources or deficits that shape human capital and labor market opportunity (Lindqvist & Vestman 2011).

School and Neighborhood Socioeconomic Conditions

In addition to experiences within the household, children and adolescents increasingly rely on school and neighborhood contexts for social interaction and resources during these critical years of cognitive development. Indeed, research documents that conditions across schools and neighborhoods have a significant impact on cognitive outcomes net of household conditions (Rutter 1985; Klebanov et al. 1998; Brooks-Gunn et al. 1993). Adolescent school contexts have clear implications for cognitive development, academic achievement, and eventual educational attainment, as schools ideally provide a cognitively stimulating and socially connected environment that promotes social and intellectual development (Roeser, Eccles, & Sameroff 2000; Barnett 1995). Neighborhoods are also thought to influence cognitive function by fostering or limiting social integration, community involvement, and use of recreational spaces. (Klebanov et al. 1998; Brooks-Gunn et al. 1993; Clarke et al. 2015).

The benefits conferred by school and neighborhood socioeconomic resources might differ depending on household SES. Among adolescents from disadvantaged households, interaction with more affluent peers and residents could enhance social and cognitive development by providing important social and financial resources, such as social and educational support, use of recreational facilities, or social capital that can be translated into educational and cognitive achievement. Alternatively, these social benefits might only be accessible to those with the household socioeconomic resources to be able to effectively utilize them.

I propose that these processes are articulated in two competing hypotheses: *resource substitution*, which argues that resources in surrounding contexts compensate for the lack of resources in the household, and *resource multiplication*, which posits that only individuals from higher SES household benefit from surrounding resources. Initially developed by Ross & Mirowsky, these hypotheses were used to examine gender differences in psychological returns to education (Ross & Mirowsky 2006; Ross & Mirowsky 2010). These hypotheses can be adapted to examine the intersection of household, neighborhood, and school conditions in shaping cognitive outcomes. First, adapting the resource substitution hypothesis, I posit that attending a more affluent school or residing in a more affluent neighborhood could mitigate the negative effects of household disadvantage on cognitive function by providing social and economic resources that compensate for the lack of household resources. On the other hand, in applying the resource multiplication hypothesis to the study of contextual effects on cognitive function, I posit that those of lower socioeconomic standing relative to other members of a school or neighborhood might be unable access to the social, material, and psychological benefits of residing in these affluent communities. Those of higher socioeconomic standing, however, might reap the benefits of school and neighborhood resources, leading to better cognitive outcomes for higher SES adolescents in affluent social settings but no difference among low SES adolescents regardless of school and neighborhood socioeconomic contexts.

Resource Substitution

Evidence supporting the role of school and neighborhood socioeconomic composition in compensating for a lack of household resources has been documented for a number of social and health outcomes, including the development of social capital (Curley 2010), engagement in delinquent behavior (Hoffmann & Dufur 2008), cognitive development (McKay et al. 1978), and adult mortality risk (Jaffe et al. 2005). In particular, the resources available in more affluent schools and neighborhoods, such as enhanced contact with and support from teachers, school and neighborhood recreational facilities, student/youth groups, and peer educational expectations, are thought to substitute for the lack of resources in the household (Jacob & Ludwig 2008). For instance, Curley (2010) used data from the HOPE VI program, which relocated low-income households to different types of neighborhoods, and identified that movement into more resource-rich communities enhanced the accumulation of social capital for low-income households. This provides quasi-experimental evidence for neighborhood resources operating as substitutes for the lack of resources within the household. In addition, Hoffmann & Durfur (2008) examined the moderating effect of school quality on the association of family capital with delinquency in adolescence, and found that high-quality school environments compensate for the lack of resources in the household to minimize involvement in delinquent behavior. Finally, McKay et al. (1978) found that school intervention programs that boost the availability of school resources increase rate of cognitive development among disadvantaged children, suggesting that school resources are particularly important for improving cognitive ability among socioeconomically disadvantaged children.

School and neighborhood socioeconomic composition may serve as important resources that substitute for low household SES to positively affect long-term cognitive outcomes. Contextual socioeconomic composition could directly affect individual outcomes due to the social capital acquired through being in close proximity to more affluent peers and neighbors. Beyond a direct compositional effect, attending a school with affluent peers or residing in a community with affluent neighbors could also be a proxy for physical resources available in the school or neighborhood, such as quality teachers and educational materials, recreational facilities, and safe communities. Regardless of the particular mechanisms, evidence of resource substitution would provide further support for efforts to desegregate schools and neighborhoods by SES, which posit that a reversal of increasing socioeconomic segregation in the U.S. will provide greater opportunity for low-SES individuals to access social and educational opportunities to ultimately achieve socioeconomic mobility (Bowman 2015; Keels et al. 2005).

Resource Multiplication

Resource multiplication posits that those from higher SES households are the most able to benefit from school and neighborhood resources, while those of lower SES are unable to access the benefits of attending a relatively affluent school or residing in an affluent neighborhood. Evidence of resource multiplication is mixed. On the one hand, evidence suggests that high-SES adolescents have the early educational background and social capital to get ahead in social and academic settings relative to lower-SES peers (Crosnoe & Schneider 2010), providing evidence for resource multiplication. Resource multiplication is also the result of lower-SES adolescents being unable to benefit from school or neighborhood affluence. For example, Crosnoe (2009) found that low-SES adolescents perform worse academically as school affluence increases, partially due to the difficulties of keeping up academically and the psychosocial consequences of being disadvantaged relative to peers. Barnett (1998) also found that although early life school interventions showed immediate academic benefits for children in poverty, these interventions did not have lasting effects on IQ in the years following, suggesting that the benefits of school resources might be short-lived for disadvantaged youth.

Evidence of resource multiplication would have very different policy implications for by highlighting the unintended consequences of school and neighborhood desegregation. Evidence of resource multiplication does not mean that these policies should not be pursued, but rather that additional policy initiatives are necessary to ensure that low-SES children and adolescents are actually able to access the benefits of more resource-rich school and neighborhood contexts, and that these benefits last into adulthood. These might include parent-level interventions to boost parent engagement in child education, or enhanced diversity training for teachers.

Underlying Mechanisms of Resource Substitution and Resource Multiplication

Table 2-1 delineates the underlying mechanisms that potentially explain resource substitution or resource multiplication. Cognitive outcomes have been shown to be influenced by *access to social and academic resources* (Carpiano, Lloyd, & Hertzman 2009; Roeser, Eccles, & Sameroff 2000; Sampson et al. 2002), *stress and mental health* (Lupien et al. 2009; McEwen & Sapolsky 1995; Sheline et al. 2006; Tarbuck & Paykel 1995), *status attainment* (Luo & Waite 2005), and *health status and behaviors* (Elias et al. 2003; Wolf et al. 2007; Ott et al. 2004; Sabia et al. 2008). However, as shown in Table 2-1, adolescents from higher- or lower-SES backgrounds might be differentially influenced by these mechanisms.

First, *social and academic resources* could provide greater cognitive benefit to those from lower-SES households, thus supporting resource substitution, or these resources could provide greater benefit to those from higher-SES households, thus aligning with resource multiplication. According to the resource substitution hypothesis, social and academic resources will be most beneficial to adolescents from low-SES households by providing a replacement for the lack of household resources, thus enabling disadvantaged adolescents to “catch up” to higher SES groups in terms of social, academic, and cognitive development. On the other hand, the resource multiplication hypothesis posits that higher-SES adolescents will be better able to access and utilize social and academic resources. Low-SES adolescents might not be able to pay for recreational and cognitively stimulating activities that benefit higher-SES adolescents, might be ostracized by more affluent peers, or might receive differential treatment from teachers and administrators. In addition, low-SES adolescents have access to resources but are unable to translate them to social and cognitive benefits. For example, disadvantaged adolescents might have lowered expectations for academic achievement compared to higher-SES adolescents through low or inconsistent educational expectations set by parents, be less able to conform to social norms in an affluent school climate, or have difficulty keeping up with school work due to previous academic disadvantaged or lower parental investment in education.

Stress and mental health could also explain the differential influence of affluent contexts on cognitive outcomes among those from higher- or lower-SES households. As shown in Table 2-1, affluent school and neighborhood contexts may be especially beneficial to adolescents from lower-SES households by providing important stress-buffering resources to those who are disproportionately more likely to be exposed to stressors and also less likely to have the social resources to cope with these stressors (Kessler 1979; Aneshensel 1992). Conversely, for adolescents from low-SES households, attending an affluent school or residing in an affluent neighborhood has the potential to induce negative outcomes due to the stress of recognizing one's lower standing relative to peers and neighbors. For low-SES adolescents, exposure to stress could not only eradicate the social benefit of belonging to affluent contexts, but could even result in worse outcomes relative to low-SES individuals who do not experience affluent schools or neighborhoods. This stress-related process is more aligned with the relative deprivation hypothesis than resource multiplication, which posits that the stress of being in a relatively lower status within a community leads to poorer health outcomes (Kondo et al. 2008; Jaffe et al. 2005; Pham-Kanter et al. 2009).

Status attainment is another potential mechanism underlying the links between socioeconomic conditions and cognitive outcomes. According to the resource substitution hypothesis, school or neighborhood affluence will compensate for the lack of resources in disadvantaged households by providing educational and occupational opportunities to all students, thus enabling low-SES adolescents to follow similar status attainment trajectories as their more affluent peers. Conversely, according to the resource multiplication hypothesis, only higher-SES adolescents will be able to achieve higher educational and occupational attainment by young adulthood, while low-SES adolescents will not be able to use school and neighborhood resources to access these status attainment trajectories.

Finally, *health status and health-related behaviors*, such as obesity, cigarette smoking, and physical inactivity, could explain socioeconomic disparities in cognitive outcomes, as well as the capacity for contextual affluence to modify these links. Aligned with the resource substitution hypothesis, adolescents from disadvantaged households are less prone to engaging in health-risk behavior if surrounded by more affluent peers who do not engage in these behaviors. Ultimately, these health-related behaviors could persist into young adulthood to affect cognitive outcomes. Conversely, according to resource multiplication, higher-SES adolescents enjoy better physical health status and are less likely to engage in health-risk behavior, while low-SES adolescents are more prone to poorer health status and engaging in negative health behaviors due to their lower relative socioeconomic position.

The Present Study

The present research draws from the life course perspective to examine how the interaction of household, school, and neighborhood conditions in adolescence predicts working memory function in young adulthood. Specifically, this study seeks to examine whether affluence in schools or neighborhoods compensates for household disadvantage in boosting long-term memory outcomes among low-SES adolescents, or whether only higher-SES adolescents reap the benefits of school and neighborhood affluence to improve later memory function. I also test the social, psychological, behavioral, and physiological processes that might underlie these interactive processes, with the ultimate goal of identifying why the impacts of household disadvantage on cognitive function differ depending on surrounding contexts.

Data

The data come from the National Longitudinal Study of Adolescent to Adult Health (Add Health), a nationally representative, school-based sample of 20,745 adolescents that were first interviewed in grades 7-12 during the 1994-95 academic year. The sampling frame for Add Health included all high schools in the United States, and a total of 80 high schools were randomly selected to participate in the survey, with an additional 52 feeder middle schools attached to the sample of high schools. Data for the in-home interview were collected through computer-assisted personal interviews for all waves of the study. Respondents were followed for four survey waves, with the most recent survey conducted in 2008. My analysis will use data from Wave I (1994-95) when respondents were age 12-18 and Wave IV (2008-09) when respondents were 24-32. Wave I adolescent and parent in-home questionnaires were conducted through a combination of computer-assisted personal interviews (CAPI) and computer-assisted self-interviews (CASI). Wave IV data was collected through a 90-minute in-home CAPI/CASI interview followed by physical measurements. Of the eligible study participants, 80.3% were interviewed in Wave IV, leaving a sample of 15,701 participants that were included in both Waves I and IV. In addition, tract-level data on neighborhood characteristics and composition was gathered from the US Census around the time of data collection for Waves I and IV. The final analytic sample consists of 10,471 participants with complete socioeconomic and cognitive data. The primary source of missing data was missing parent interviews (which are necessary to measure adolescent household income); among respondents interviewed in Wave IV, approximately 15% of participants did not have Wave I parent interviews. Multiple imputation was conducted to maximize the sample size among those missing income and cardiometabolic risk measures. Imputation was not conducted among those missing the entire parent interview due to missing data among other indicators needed for imputation. Multiple imputation increased the analytic sample by approximately 31%.

Measures

Young adult *working memory function* was measured by combining three memory tasks administered at Wave IV: immediate word recall, delayed word recall, and number recall. For the immediate word recall task, Add Health interviewers read a list of 15 words to respondents, after which respondents were given one minute to recall as many words as they could. The number of correctly recalled words was included in the index of memory function. For the delayed recall task, respondents were asked to repeat the words from the immediate word recall task several minutes later (interview items regarding mental health were asked in between memory tasks). Consistent with scoring for the immediate word recall task, the number of words correctly recalled in the delayed word recall task was added to the index of memory function. Finally, for the number recall task, respondents were read a number series and asked to repeat the number series backward to the interviewer (for example, if the interviewer said “3, 8,” the correct response would be “8, 3”). Items for the number recall task became progressively more difficult, with the first item asking respondents to repeat two numbers, and the last item asking respondents to repeat eight numbers (7 items total). Collectively, these tasks assess working memory function (Baddeley 1992). Combining these three tasks produced a continuous scale of memory function with a possible range of 0-37. In addition to a continuous measure of working memory, a binary measure of memory impairment was constructed by coding the bottom quartile of the continuous scale as memory impaired.

Adolescent household SES was measured using several indicators of parent SES in Wave I, including household income, parent educational attainment, parent unemployment, and residing in a single parent household. Household income was coded as a three-category measure to capture the bottom quartile, middle quartiles, and top quartile of the income distribution within the sample. A binary indicator of low household income was constructed by coding the lowest income quartile as low income. Parent educational attainment was coded as a four-category measure, with 1=less than high school, 2=high school degree or equivalent, 3=some college, and 4=college graduate or more. In two-parent households, the maximum educational attainment among both parents was used. Adolescent reports of parent education from in-home interviews or in-school surveys were used among those who were missing parent reports of educational attainment. A binary indicator of low parent education was constructed by coding parents with less than a high school degree as low-educated. A binary indicator of parent unemployment was created based on parent reports of current unemployment. Parents were asked, “Are you unemployed right now, but looking for a job?” In two-parent households, unemployment of either parent was coded as unemployed. Consistent with the parent education measure, adolescent reports of parent unemployment were used among those missing parent reports of unemployment. Finally, a binary indicator of single parent household was constructed based on the household roster completed by respondents.

An *adolescent school affluence index* was constructed from in-school surveys by aggregating respondent reports of SES to the school level. The in-school surveys were used to construct the school disadvantage index rather than the in-home interviews because more students completed the in-school survey (N~90,000) compared to the in-home interview (N~20,000), making responses from the in-school survey more representative of school-level socioeconomic characteristics. Four indicators were used to construct the school affluence index, including the proportion of households with a parent who holds a college degree, the proportion of households with a parent who is employed in a managerial or professional position, the proportion of two-parent households, and the proportion of households who receive welfare or public assistance (reverse coded). Items from the in-home interview were used for respondents who were missing in-school surveys. A binary affluence indicator was created for each item to identify schools in the top quartile of prevalence for each affluence indicator. Taking the sum of these four binary measures produced a school disadvantage index for each school with a range of 0-4. A binary indicator of school affluence was constructed by coding schools with three to four affluence indicators as affluent.

An *adolescent neighborhood affluence index* was created from tract-level Census data from 1990. The index was constructed based on five affluence indicators that capture tract-level median household income, proportion with a college degree, cost of homes, proportion working in a managerial occupation, and low prevalence of welfare receipt. Each item was dichotomized to indicate higher affluence and summed to create a neighborhood affluence index ranging from 0-5 for each wave. To capture participants who resided in affluent neighborhoods across multiple socioeconomic domains, the index was recoded as a binary indicator of neighborhood affluence, with neighborhoods with an affluence score of three or more were coded as affluent.

Underlying mechanisms were measured as follows. Several measures of *adolescent social and academic resources* were constructed using Wave I in-home interviews and in-school surveys. For school connectedness, respondents were asked how much they feel "close to people at this school," "a part of this school," and "happy at this school." Response categories ranged from (1) strongly agree to (5) strongly disagree. For each item, responses were recoded as binary indicators, such that "agree" or "strongly agree" reflected stronger school connectedness, and each indicator was then summed to create an index ranging from 0-3. Parent support was measured using 13 subjective indicators of relationship quality with each parent, including whether each parent is "warm and loving," cares about the respondent, and whether the respondent is satisfied with communication, closeness, and the overall relationship with parents. Each item was recoded as a binary indicator, and summed so higher scores reflecting higher support. Teacher support was constructed from a single variable that asks whether teachers at school "care about you," and was recoded as a binary measure with "agree" or "strongly agree" indicative of high support. Two measures of adolescent-perceived parent expectations for high school and college completion were also included as measures adolescent social resources. Respondents were asked to rank on a scale of 1-5 how disappointed their parents would be if they "did not graduate from high school" or "did not graduate from college." Neighborhood connectedness was measured using six indicators of neighborhood integration, including whether the respondent knew people in the neighborhood, spoke to people in the neighborhood, perceived that people in the neighborhood "look out for each other," used a recreational facility in the neighborhood, felt safe in the neighborhood, and felt happy in the neighborhood. Items were recoded as binary indicators and summed to create a scale from 0-6, with higher scored indicating higher connectedness. Finally, a composite measure of school strain was created to reflect social and academic strain in school. Measures of school strain included an indicator of problems with getting homework done, getting along with peers, getting along with teachers, and paying attention in school. In addition, school strain included three additional items that capture ever experiencing a suspension or expulsion, perception of prejudice among peers, and perception that teachers treat students unfairly. The final school strain scale ranges from 0-4, with higher scores indicating higher strain.

Academic performance was measured using adolescent reports of grades received in English, mathematics, science, and social studies. If no grade was reported during the in-home interview, missing values were replaced with reported grades during the in-school survey. Grade point average (GPA) was calculated by averaging the grades that students reported. Adolescents who reported fewer than three grades were coded as missing. Values range from 1 to 4, with higher values reflecting higher grades.

Adolescent mental health was measured by constructing two continuous indicators of self-esteem and depressive symptoms. Self-esteem was measured by summing nine items that asked respondents whether they felt they "have a lot of good qualities," are "physically fit," "have a lot to be proud of," like themselves, are "doing everything just about right," are "socially accepted," and are "loved and wanted." An abbreviated CES-D scale consisted of nine items that reflect depressive symptomology. CES-D items prompted respondents to report how often they "were bothered by things that usually don't bother you," "felt you could not shake off the blues," "felt you were just as good as other people" (reverse coded), "had trouble keeping your mind on what you were doing," "felt depressed," "were too tired to do things," "enjoyed life" (reverse coded), "felt sad," and "felt that people disliked you" over the past week. Responses ranged from "never or rarely" (0) to "most of the time or all of the time" (3), and were summed to create a continuous scale ranging from 0-27, with higher scores reflecting more depressive symptoms.

Status attainment was measured using young adult reports of household income and educational attainment in Wave IV. Household income was coded to reflect the bottom income quartile, middle quartiles, and top quartile within the sample. A binary indicator of low household income was constructed, with the lowest quartile coded a low income. Consistent with parent education, respondent education followed the following coding scheme: 1=less than high school, 2=high school graduate or equivalent, 3=some college, and 4=college degree or more. A binary indicator of low educational attainment was constructed with "less than high school" and "high school graduate or equivalent" coded as low-educated.

Two measures of *adult mental health* from Wave IV were used, including the abbreviated CES-D depression scale and the perceived stress scale (PSS). CES-D items and measurement is identical to measurement in Wave I. The PSS is composed of four items that ask respondents how often they felt they "were unable to control the important things in your life," "felt confident in your ability to handle personal problems" (reverse coded), "felt things were going your way" (reverse coded), and "felt that difficulties were piling up so high that you could not overcome them." PSS items were recoded so responses of "fairly often" or "often" were coded as high perceived stress, and summed to create a scale ranging from 0-4.

Adult health behaviors included a binary indicator of currently smoking cigarettes, a continuous measure of the frequency of alcohol consumption (ranging from 0-6), and a continuous measure of the frequency of engaging in physical activities, such as bicycling, doing aerobics, participating in team or individual sports, or walking for exercise over the past week (range 0-49). Further, a binary measure of cardiometabolic risk was constructed to capture physiological function across cardiovascular, immune, and metabolic systems. Seven items were used to measure cardiometabolic risk: hypertension, C-reactive protein, abdominal obesity, hemoglobin A1c, high-density lipoprotein (reverse coded), low-density lipoprotein, and triglycerides. Respondents with four or more high-risk physiological indicators were coded as high cardiometabolic risk.

In addition to mediators, several items were included in the analysis to adjust for possible selection and confounding. A measure of *school and neighborhood selection* was included to control for non-random assignment of respondents to particular school or neighborhood conditions. Selection into schools and neighborhoods was measured using a parent interview item that asked whether parents chose their particular neighborhood because of the schools. *Adolescent cognitive ability* includes one continuous measure of respondent scores on the Picture Vocabulary Test (PVT), which was administered in Wave I. The PVT is a measure of verbal ability that is often used as a proxy for cognitive ability. Adjustment for baseline cognitive ability tests whether socioeconomic disparities in cognitive abilities that have already emerged in adolescence might account for the relationship between adolescent socioeconomic conditions and memory function by young adulthood. Put another way, adjustment for adolescent cognitive ability allows for assessment of associations between adolescent socioeconomic conditions and young adult memory function net of cognitive status at baseline. *Parent-reported cognitive deficit* was used as an additional indicator of baseline cognitive status of adolescents, with 1= "mentally retarded." Finally, a scale of *conscientiousness* was included to adjust for personality traits that could influence both adolescent achievement and adult effort in completing the cognitive tasks during the study. Conscientiousness was measured using four items from the Mini International Personality Item Pool that ask whether respondents "get chores done right away," "like order," "make a mess of things" (reverse coded) and "forget to put things back in their proper place" (reverse coded). Items were coded on a Likert scale, with 1=strongly disagree and 5=strongly agree, then averaged to produce a conscientiousness scale ranging from 1-5.

Analysis

I conducted multilevel analysis to test the additive and interactive associations of adolescent household socioeconomic conditions, school affluence, and neighborhood affluence with young adult working memory. Multilevel modeling accounts for the clustered structure of the data (individuals sampled within schools), and is also best suited for research that examines how interactions of socioeconomic conditions across contexts affect individuals (Raudenbush & Bryk 2002). Specifically, I used multilevel linear regression to test the associations of adolescent socioeconomic conditions with a continuous indicator of young adult memory function, and multilevel logistic regression to test for associations of adolescent conditions with a binary measure of memory impairment. Linear estimates are reported as regression coefficients, and estimates from logistic models are reported as odds ratios (OR) with 95% confidence intervals (CI). All models adjust for sex, race/ethnicity, and age. Sampling weights were applied to all analyses to account for unequal chances of selection, and error variances were adjusted to account for the clustered sampling design by school and U.S. region.

Results

Descriptive statistics for the key variables of interest are shown in Table 2-2. Young adult working memory is normally distributed with a mean of 16.0 and a range of 0-37, thus covering the full range of possible scores. Adolescent household income ranged from \$0-\$999,000, with the lowest income quartile making less than \$23,000 annually. This value is higher than U.S. poverty thresholds for a family of three or four in 1996, which were approximately \$12,980 and \$15,600, respectively (U.S. Census Bureau 1996). However, research suggests that families typically need an income of at least twice the federal poverty line to meet basic needs (Jiang et al. 2016), thus making the lowest income quartile representative of households who may have been above the poverty threshold but who were still economically deprived. Further, though the majority of parents had a maximum educational attainment of some college or more, 11% of households had parents who did not earn a high school degree, and 27% had only a high school diploma. In terms of socioeconomic contexts outside of the home, 21% of adolescents resided in affluent neighborhoods (that is, neighborhoods that had three or more positive indicators of affluence). In addition, 16% of schools (8 schools out of 126) were coded as affluent because these schools had three or more positive indicators of school affluence.

Table 2-3 shows additive associations of adolescent socioeconomic conditions across households, schools, and neighborhoods with young adult memory function and memory impairment.[1] Model I shows significant associations of adolescent household income and parent education with young adult memory function and impairment. Residing in a household in the top income quartile is associated with a 0.57-point increase in the memory function score (p<0.001), and parent education is associated with a 0.91-point decrease in memory function among those with parent education of less than high school compared to those with a high school degree (p=0.001), and a 0.40 and 0.85 increase in memory function among those with parent education of some college or college or more, respectively (p=0.004, p<0.001). While these associations appear to be modest in magnitude, Model IV shows more pronounced associations of adolescent household socioeconomic conditions with odds of memory impairment. Residing in a household in the top income quartile is associated with 24% lower odds of memory impairment in young adulthood (OR 0.76, 95% CI 0.63-0.92). Further, low parent educational attainment (less than high school) is associated with 48% higher odds of memory impairment, and parent attainment

[1] A null multilevel model to test for school-level variation in young adult working memory showed significant school-level differences in memory function, with 17% of the variance in memory function explained by school, thus demonstrating that multilevel modeling is necessary to examine the contextual contributors to memory function.

of a college degree or more is associated with 35% lower odds of memory impairment in young adulthood. Interestingly, parent unemployment is associated with an increase in memory function (coef. 0.67, p=0.029). No association of the association of residing in a single parent household with memory function was found.

Table 2-3 also shows direct associations of school and neighborhood affluence with memory function. Attending a school with affluent peers is associated with a 1.07-point increase in the memory function scale (p=0.003), and residing in an affluent neighborhood is associated with a 0.37-point increase in memory function (p=0.038) and 22% lower odds of memory impairment (OR 0.78, 95% CI 0.64-0.95). Models II and VI show that these associations of school and neighborhood affluence are mostly attenuated by inclusion of household socioeconomic characteristics, with the exception of school affluence, which remains associated with a 0.70-point increase in memory function after adjusting for household factors (p=0.045).

Table 2-4 shows the interactive associations of socioeconomic conditions across contexts with memory function and impairment. Model I shows a significant interaction of low household income with school affluence, such that the income gap in young adult memory function is larger among adolescents who attended affluent schools relative to those in non-affluent schools. In other words, results indicate that low-income adolescents fair worse in affluent schools relative to adolescents who are not low income, and this income disparity is wider in affluent schools relative to non-affluent schools. In addition, Model IV shows that the income gap in memory impairment is also larger in affluent schools compared to non-affluent schools. Low-income adolescents also fair worse relative to adolescents who are not low-income when residing in affluent neighborhoods. The interaction in Model II demonstrates that the income gap in young adult memory function is larger in affluent neighborhoods relative to non-affluent neighborhoods, though this interaction is marginally significant. Results for cognitive impairment, however, demonstrate that the income gap in cognitive impairment is significantly different across neighborhood contexts (Model V). No significant interactions were observed for low parent educational attainment and school or neighborhood affluence. Collectively, these results provide support for the resource multiplication hypothesis for low household income, but not for low parent educational attainment.

Figure 2-1 illustrates findings in Table 3 by plotting predicted values of memory function and probabilities of memory impairment by household income when models are stratified by school and neighborhood affluence. Figure 1a shows no significant association of adolescent household income with young adult memory function among respondents who attended non-affluent schools. In other words, the income gap is small and not significant among adolescents who do not attend affluent schools, with predicted values of 15.9 and 16.2 among low-income and higher-income adolescents, respectively. However, among those who attended affluent schools, the income gap in young adult memory function is larger and statistically significant (16.2 and 17.5 among low-income and higher-income adolescents, respectively). Further, the difference in the income gap across non-affluent and affluent schools appears to be driven by elevated memory function among adolescents from higher income households who attend affluent schools, while there appears to be no difference in memory function for adolescents in low-income households regardless of school affluence. These results provide support for the resource multiplication hypotheses, whereby individuals who are of higher SES are able to reap the additional benefits of affluent school contexts, while low SES individuals are unable to access these beneficial cognitive resources.

Figure 2-1b illustrates differences in the association of household income with memory function that are dependent on neighborhood affluence. Similar to differences across school socioeconomic contexts, Figure 2-1b shows no significant association of household income with memory function in non-affluent neighborhoods, but shows significantly higher memory function for higher-income respondents in affluent neighborhoods relative to low-income respondents in the same neighborhoods. Figures 2-1c and 2-1d show similar results for cognitive impairment, such that higher-income adolescents benefit from affluent school and neighborhood contexts, but no difference is seen among low-income respondents who experience affluent or non-affluent settings. This provides further support for the resource multiplication hypothesis.

Table 2-5 shows analysis among a subsample of respondents from affluent schools or neighborhoods to test for mechanisms that might explain resource multiplication among higher income adolescents that ultimately affects young adult memory. Estimates in column I show baseline associations of low household income in adolescence with memory outcomes (function and impairment) in young adulthood among respondents from affluent schools or neighborhoods. Compared to adolescents from high- or middle-income households who attend affluent schools, adolescents from low-income households who attend the same schools score 1.5 points lower on the memory tasks ($p<0.001$), and have more than twice the odds of cognitive impairment (OR 2.08, 95% CI 1.34-3.22). Results for adolescents residing in affluent neighborhoods are similar, as adolescents from low-income households score 1.6 points lower on the memory tasks compared to those from high- or middle-income households ($p=0.001$), and have 2.5 times higher odds of cognitive impairment (OR 2.45, 95% CI 1.47-4.10). Estimates in column II show slight attenuation after adjustment for school/neighborhood selection, adolescent cognitive ability, adolescent cognitive deficits, and conscientiousness. For example, among those from affluent neighborhoods, the association of adolescent low household income with young adult memory function diminishes from -1.61 to -1.11, yet remains statistically significant. Estimates in columns III-IX reveal that the association of adolescent household income with memory outcomes in affluent settings is partially or fully explained by mediating processes. Status attainment by young adulthood appears to be an important mediating mechanism linking household income to cognitive outcomes in affluent settings. Looking at models in column XI, among those from affluent school contexts, the association of low household income with memory function is partially attenuated by status attainment (coef. -0.93, p=0.027), and the association of low household income with memory impairment is fully attenuated by status attainment (OR 1.45, CI 0.92-2.29). Among those from affluent neighborhood contexts, the association of household income with memory function is fully attenuated by status attainment (coef. -0.74, p=0.101), and the association of household income with memory impairment is partially attenuated by status attainment (OR 1.85, CI 1.10-3.11). Appendix 1 shows four tables with estimates for all covariates in the mediation models.

Discussion

Using a longitudinal, nationally representative sample of U.S. adolescents followed across the transition to adulthood, this study examined the differential impacts of household socioeconomic disadvantage on young adult memory function across school and neighborhood socioeconomic contexts. I tested two competing hypotheses for the moderating influence of contextual affluence on associations between household disadvantage and memory outcomes; the resource substitution hypotheses, which posits that exposure to greater socioeconomic resources in the school and neighborhood compensates for disadvantage in the household to boost memory function, and the resource multiplication hypothesis, which argues that low-SES individuals are unable to reap the cognitive benefits of contextual affluence that higher-SES individuals enjoy. I find partial evidence for resource multiplication, such that adolescents from middle- to high-income households benefit from affluent school and neighborhood settings, while adolescents from low-income households do not. These results are robust after adjustment for school and neighborhood selection, adolescent cognitive ability, and conscientiousness. Further, in testing the mediators that underlie resource multiplication for family income, I found that status attainment is a primary mechanism that drives socioeconomic differences in cognitive outcomes.

Evidence of resource multiplication for those with higher household income is consistent with prior research that finds higher SES students have the social and cultural capital to achieve better in school, while low-SES students have greater academic difficulties and challenges with social and psychological adjustment to the school setting (Crosnoe 2009; Crosnoe & Schneider 2010). However, mechanisms related to adolescent social resources and psychological health did little to explain the income gap in memory outcomes among respondents from affluent settings, suggesting that other adolescent resources or different long-term mechanisms underlie these associations. Indeed, status attainment by young adulthood appeared to explain a substantial portion of the income gap in memory function, as adolescents from low-income households were less likely to receive education beyond high school and were more likely to reside in low-income households by young adulthood. Adult health behaviors also appeared to partially mediate socioeconomic disparities in memory function, particularly cigarette smoking.

The association of parent educational attainment with young adult memory function was not significantly different across school and neighborhood contexts. In other words, parent education appeared to matter equally for memory outcomes regardless of school or neighborhood context, possibly because adolescents of more educated parents acquire social and cognitive resources from the household, which translates into better cognitive outcomes when in any school or neighborhood. Meanwhile, adolescents of low-educated parents have more limited educational resources in the household that affects cognitive outcomes regardless of surrounding contexts.

These findings do not mean that improving school and neighborhood conditions have no benefit for disadvantaged youth; rather, they suggest that policy changes and interventions within schools and neighborhoods are necessary to enable disadvantaged adolescents to access resources important for cognitive development and status attainment. Further, interventions at the household-level, including income support programs and conditional cash transfers, could improve household socioeconomic conditions and ultimately the ability for adolescents to access social and educational resources outside of the home (Magnuson 2013). Finally, individual-level interventions to improve the educational and labor market prospects of current and future parents will enable the intergenerational transmission of forms of capital that ultimately improve cognitive outcomes.

This study has several limitations that warrant further research. First, the present study relies on observational data and therefore cannot rule out reverse causation. For example, it is possible that respondents with higher cognitive function are selected into more affluent socioeconomic contexts due to the higher cognitive ability of parents, and this higher cognitive ability is then genetically transmitted to offspring. However, these selection processes are likely to be modest due to statistical adjustments for selection. In tests of the mechanisms related to socioeconomic disparities in memory function among those in affluent contexts, I adjust for the adolescent Picture Vocabulary Test, which is a proxy cognitive ability, meaning that estimates reflect memory function in young adulthood net of adolescent cognitive ability. I also adjust for parents' decisions to reside in their home neighborhoods because of the schools to account for selection into schools based on parental preferences. Beyond these adjustments, further research that incorporates genetic data is needed to account for genetic processes.

A second limitation is the measurement of memory function, which consists of several working memory tasks. While working memory often reflects global cognitive abilities (Conway, Kane, & Engle 2003), a more extensive cognitive battery would capture cognitive function across memory, problem solving, and attention processes with greater accuracy. Therefore, these research questions should be reexamined when more extensive cognitive data is available for young adults. Third, while the data I use captures socioeconomic conditions in adolescence, prior research shows that socioeconomic disparities in cognitive development begin in utero and continue to grow through childhood (Golden et al. 1968; Kishiyama et al. 2009; Hackman & Farah 2002). This topic should be reexamined using longitudinal data that begins in childhood and continues into adulthood once such data becomes available. Finally, while I find little evidence of resource- or stress-related mechanisms underlying resource multiplication processes, this could be due to limited measures of these mechanisms. Additional measures of adolescent resources, including objective indicators of peer support and integration, classroom-level measures of peer interaction and student-teacher relationships, and adolescent indicators of stressor exposure could provide additional insight into the processes that explain socioeconomic disparities in working memory outcomes.

Overall, this research contributes to cross-disciplinary literature that seeks to identify the complex determinants of cognitive function across the life span. These findings challenge current understandings of the socioeconomic contributors to cognitive outcomes by emphasizing the need to examine how early life household socioeconomic contexts intersect with experiences in schools and neighborhoods to shape long-term socioeconomic and cognitive trajectories. Future work should continue to build on this intersectional framework to examine how the interaction of early life socioeconomic contexts shape cognitive function from childhood to old age, thus providing further evidence for the role of early life contexts on late life cognitive outcomes.

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Table 2-1. *Mechanisms of Resource Substitution and Resource Multiplication*

Mechanism	**Resource Substitution**	**Resource Multiplication**
Access to Social & Academic Resources	Resources from peers, teachers, and neighbors in more affluent settings will compensate for lack of resources in the household.	Only adolescents from higher-SES households will be able to access and utilize surrounding resources.
Stress & Mental Health	The greater order, stability and support available in more affluent settings will buffer against the negative impacts of stress exposure in the household.	Higher-SES adolescents will benefit from stress-buffering resources, while lower-SES adolescents will experience higher stress due to relatively lower social standing (relative deprivation).
Status Attainment	Acquisition of school and neighborhood resources in adolescence will enable upward mobility among lower-SES adolescents.	Higher-SES adolescents will be better able to use social and academic resources for educational and occupational attainment than lower-SES adolescents.
Health Status & Behaviors	Lower-SES adolescents will be less prone to engaging in health-risk behavior if surrounded by more affluent peers who do not engage in these behaviors.	Higher-SES adolescents will be less likely to engage in health-risk behaviors, while lower-SES adolescents will engage in poorer health behaviors to cope with low relative status.

Table 2-2. *Descriptive Statistics: Add Health (N=10,471)*

	Mean (SD) or %	Range
Dependent Variable		
Memory function	16.0 (4.4)	0-37
Adolescent Socioeconomic Conditions		
Adolescent household income (thousands)[a]	46.3 (50.8)	0-999
Bottom quartile (<$23,000; %)	25.5	
Middle quartiles ($23,000-$60,000)	53.3	
Top quartile (>$60,000)	21.1	
Parent education (%)		
Less than HS	11.0	
HS or equivalent	26.8	
Some college	31.6	
College or more	31.0	
Parent unemployment (%)	6.6	
Single parent household (%)	44.5	
Neighborhood affluence (%)	21.1	
School affluence[b] (%)	15.7	
Demographic Controls		
Female (%)	48.8	
Age (adolescence)	15.2 (1.7)	11-21
Race/ethnicity		
White	65.5	
Black	17.2	
Hispanic	10.8	
Other	6.5	
Confounders & Selection Processes		
Picture Vocabulary Test score (adolescence)	101.9 (14.1)	14-146
Parent select neighborhood b/c of schools (%)	13.6	
Parent-reported cognitive deficit	1.0	
Conscientiousness	3.6 (0.7)	1-5
Adolescent Social Resources		
School connectedness	2.1 (1.1)	0-3
Parent support	9.3 (3.3)	0-13
Teacher support (%)	52.6	
Parent expects HS graduate	4.8 (0.8)	1-5
Parent expects college graduate	4.1 (1.2)	1-5
Neighborhood connectedness	4.1 (1.3)	0-6
School strain	1.2 (1.1)	0-4
Adolescent Academic Performance		
Grade point average		
A	8.5	
B	40.1	
C	39.0	
D or lower	12.4	
Adolescent Mental Health		
Self esteem	5.8 (1.6)	0-9
CES-D scale (adolescence)	5.6 (4.2)	0-27
Status Attainment		
Adult household income[a]		
Bottom quartile (<$30,000; %)	21.9	
Middle quartiles ($30,000-$75,000)	47.6	
Top quartile (>$75,000)	30.5	
Respondent education (%)		
Less than HS	8.7	
HS or equivalent	17.6	
Some college	43.5	
College or more	30.2	

Adult Mental Health		
CES-D scale (adulthood)	5.2 (4.1)	0-27
Perceived stress scale	0.5 (0.9)	0-4
Adult Health Behaviors		
Current cigarette smoker (%)	24.4	
Alcohol consumption	2.3 (1.8)	0-6
Physical activity	6.3 (6.0)	0-49
Cardiometabolic risk (%)	17.7	

[a]Based on non-imputed data (N=7,228)

[b]Based on school-level data (N=126 schools)

***Table 2-3**. Associations of Adolescent Socioeconomic Conditions with Memory Function and Impairment (N=10,471)*

	Memory Function (continuous)			Memory Impairment (dichotomous)		
	I	**II**	**III**	**IV**	**V**	**VI**
FIXED EFFECTS						
Intercept	21.19***	22.34***	21.02***	0.01***	0.01***	0.01***
	(1.32)	(1.36)	(1.33)	(0.00 - 0.05)	(0.00 - 0.03)	(0.00 - 0.05)
Family income (ref. 2nd-3rd quartiles)						
Bottom quartile	-0.11		-0.10	1.07		1.07
	(0.19)		(0.19)	(0.88 - 1.31)		(0.88 - 1.30)
Top quartile	0.57***		0.55**	0.76**		0.77**
	(0.17)		(0.17)	(0.63 - 0.92)		(0.64 - 0.93)
Parent education (ref. HS graduate)						
Less than HS	-0.91**		-0.92**	1.48***		1.48***
	(0.28)		(0.28)	(1.18 - 1.86)		(1.18 - 1.86)
Some college	0.40**		0.39**	0.85†		0.86†
	(0.14)		(0.14)	(0.72 - 1.02)		(0.72 - 1.02)
College or more	0.85***		0.82***	0.65***		0.66***
	(0.19)		(0.19)	(0.53 - 0.79)		(0.54 - 0.80)
Parent unemployment	0.67*		0.67*	0.80†		0.80†
	(0.31)		(0.31)	(0.61 - 1.04)		(0.62 - 1.04)
Single parent household	-0.07		-0.08	0.95		0.95
	(0.15)		(0.15)	(0.84 - 1.09)		(0.84 - 1.08)
School affluence		1.07**	0.70*		0.64†	0.77
		(0.36)	(0.35)		(0.38 - 1.06)	(0.47 - 1.27)
Neighborhood affluence		0.37*	0.10		0.78*	0.87
		(0.18)	(0.17)		(0.64 - 0.95)	(0.72 - 1.06)
RANDOM EFFECTS						
Variance components						
School	0.30	0.35	0.27	1.74†	1.84†	1.71†
	(0.44)	(0.43)	(0.44)	(0.93 - 3.24)	(0.93 - 3.66)	(0.92 - 3.17)
Individual	1.39***	1.40***	1.39***			
	(0.02)	(0.02)	(0.02)			

Standard errors or 95% CI in parentheses.
*** p<0.001, ** p<0.01, * p<0.05, † p<0.1
Note: All models adjust for age, race/ethnicity, sex.

Table 2-4 *Moderating Effects of School and Neighborhood Affluence on the Associations of Household Disadvantage with Memory (N=10,471)*

	Memory Function (continuous)				Memory Impairment (dichotomous)			
	I	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**
FIXED EFFECTS								
Intercept	22.40***	22.53***	22.04***	22.20***	0.01***	0.01***	0.01***	0.01***
	(1.35)	(1.33)	(1.33)	(1.32)	(0.00 - 0.03)	(0.00 - 0.03)	(0.00 - 0.03)	(0.00 - 0.03)
Low family income	-0.40*	-0.46**			1.26*	1.21*		
	(0.17)	(0.17)			(1.05 - 1.52)	(1.01 - 1.46)		
Parent less than HS			-1.37***	-1.30***			1.78***	1.72***
			(0.28)	(0.27)			(1.45 - 2.18)	(1.41 - 2.10)
School affluence	1.25***		1.03**		0.62†		0.65	
	(0.38)		(0.35)		(0.39 - 1.01)		(0.39 - 1.09)	
Neighborhood affluence		0.48*		0.43*		0.78*		0.81*
		(0.19)		(0.18)		(0.64 - 0.94)		(0.66 - 1.00)
Low family income X School affluence	-1.22**				1.71*			
	(0.44)				(1.09 - 2.69)			
Low family income X Neighborhood affluence		-0.78†				1.83**		
		(0.45)				(1.17 - 2.85)		
Parent less than HS X School affluence			0.72				1.17	
			(1.21)				(0.47 - 2.91)	
Parent less than HS X Neighborhood affluence				-0.50				1.44
				(0.56)				(0.76 - 2.73)
RANDOM EFFECTS								
Variance Components								
Schools	0.35	0.39	0.27	0.30	1.81†	1.91†	1.68†	1.74†
	(0.43)	(0.44)	(0.41)	(0.42)	(0.92 - 3.53)	(0.92 - 3.98)	(0.96 - 2.96)	(0.98 - 3.10)
Individuals	1.40***	1.40***	1.40***	1.40***				
	(0.02)	(0.02)	(0.02)	(0.02)				

Standard errors or 95% CI in parentheses.
*** p<0.001, ** p<0.01, * p<0.05, † p<0.1
Note: All models adjust for age, race/ethnicity, and sex.

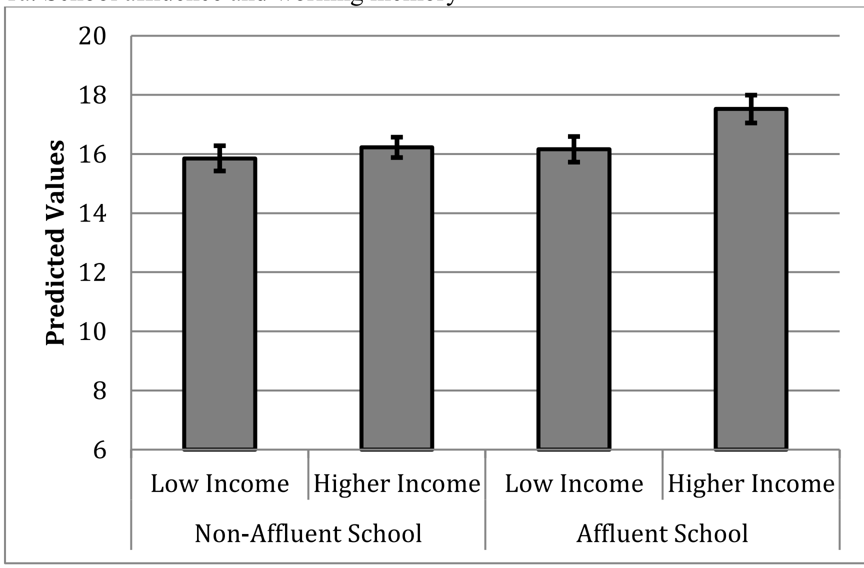
***Table 2-5**. Mediating Mechanisms*

	I	II	III	IV	V	VI	VII	VIII	IX
	Baseline	Selection Processes	Adolescent Resources	Academic Performance	Adolescent Mental Health	Status Attainment	Adult Mental Health	Adult Health Behaviors	Full Model
Memory Function (continuous)									
School Affluence (N=1,324)									
Low household income	-1.54***	-1.31**	-1.17**	-1.14**	-1.26**	-0.93*	-1.29**	-1.10**	-0.80*
	(0.44)	(0.46)	(0.44)	(0.43)	(0.45)	(0.44)	(0.47)	(0.37)	(0.40)
Neighborhood Affluence (N=2,142)									
Low household income	-1.61***	-1.11*	-1.11*	-0.97*	-1.09*	-0.74	-1.01*	-0.94*	-0.65
	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.47)
Memory Impairment (dichotomous)									
School Affluence (N=1,324)									
Low household income	2.08**	1.78*	1.78*	1.71*	1.77*	1.45	1.70*	1.65*	1.43
	(1.34-3.22)	(1.14-2.77)	(1.11-2.85)	(1.09-2.69)	(1.14-2.75)	(0.92-2.29)	(1.07-2.70)	(1.04-2.62)	(0.86-2.39)
Neighborhood Affluence (N=2,142)									
Low household income	2.45***	2.12**	2.24**	2.04**	2.13**	1.85*	2.04**	1.99*	1.91*
	(1.47-4.10)	(1.24-3.62)	(1.32-3.81)	(1.23-3.38)	(1.24-3.63)	(1.10-3.11)	(1.20-3.46)	(1.14-3.45)	(1.14-3.22)

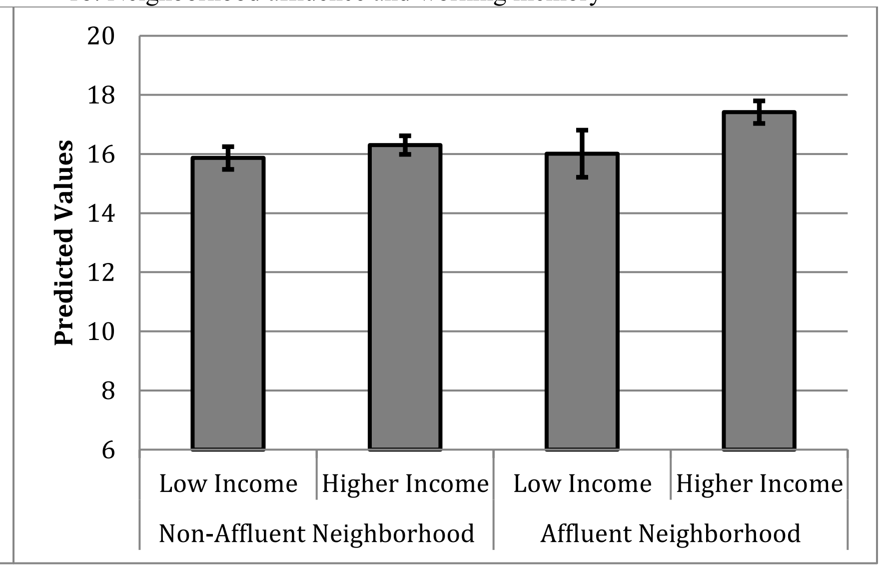
Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1
All models adjust for age, race/ethnicity, and sex.
Model building:
Models in column I adjust for age, race/ethnicity, and sex only.
II adjust for selection processes (adolescent PVT score, adolescent cognitive deficit, selection of neighborhood for schools, and conscientiousness).
III adjust for selection processes, school connectedness, neighborhood connectedness, parent support, teacher support, parent educational expectations, and school strain.
IV adjust for selection processes and adolescent grade point average (GPA).
V adjust for selection processes, adolescent self-esteem, and adolescent depressive symptoms.
VI adjust for selection processes, educational attainment in young adulthood, and household income in young adulthood.
VII adjust for selection processes, adult depressive symptoms, and adult perceived stress.
VIII adjust for selection processes, young adult cigarette smoking, alcohol consumption, physical activity, and cardiometabolic risk.
IX adjust for all variables.

Figure 2-1. *Predicted Values and Predicted Probabilities of Associations of Adolescent Household Income with Memory*

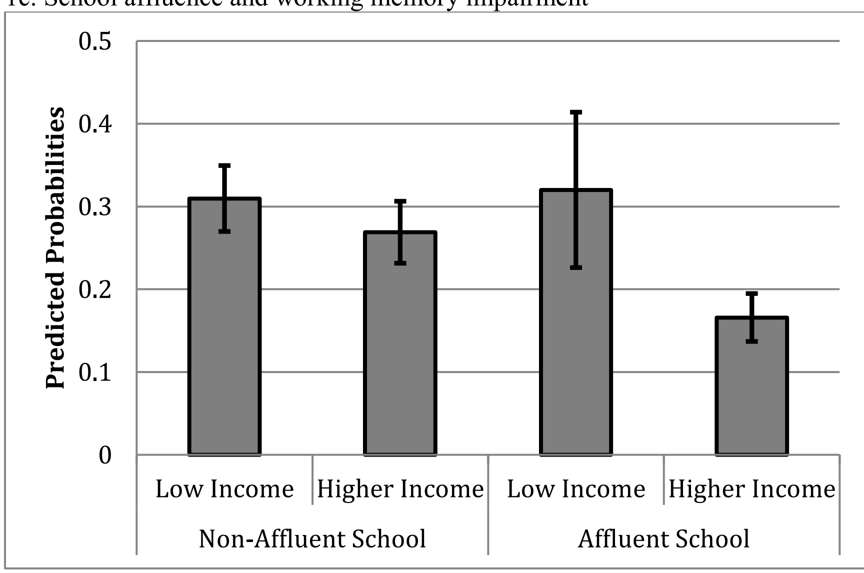
1a. School affluence and working memory



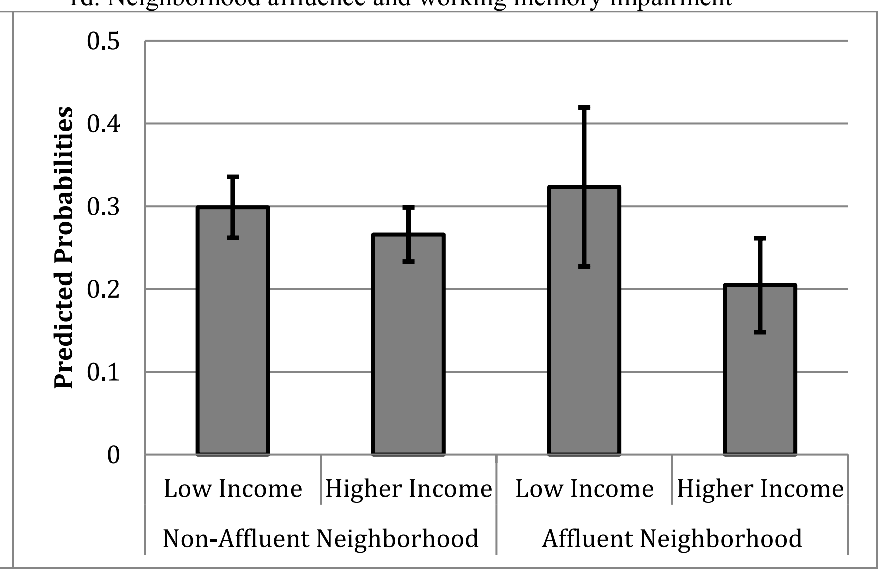
1b. Neighborhood affluence and working memory



1c. School affluence and working memory impairment



1d. Neighborhood affluence and working memory impairment



CHAPTER THREE: EARLY LIFE DISADVANTAGE AND COGNITIVE RESILIENCE ACROSS THE LIFE SPAN: DOES CONSCIENTIOUSNESS MATTER?

Abstract

While previous literature cites early life socioeconomic conditions as a significant predictor of adult cognitive function, the substantial inter-individual variation in the links between early life conditions and adult cognition remains poorly understood. Conscientiousness is a protective personality characteristic that has the potential to buffer against the negative impacts of childhood disadvantage, thus explaining why some might be less prone to the negative impacts of disadvantage than others. Using the National Survey of Midlife Development in the U.S. (MIDUS), the present study tests the moderating effect of conscientiousness on the association of early life socioeconomic disadvantage with adult cognitive function. In addition, this work tests whether the interaction between early life disadvantage and conscientiousness differs by age. Results show little influence of early life socioeconomic disadvantage on cognitive function among those who are highly conscientious, while those who are not conscientious are more prone to the negative cognitive impacts of early life disadvantage. Further, this interaction differs by age, whereby the protective effect of conscientiousness among those from disadvantaged backgrounds is most apparent in midlife and dissipates by late adulthood. Adjustment for social, psychological, and behavioral processes explains little of the moderating effect of conscientiousness on the association between early life disadvantage and cognitive function in midlife.

Introduction

A growing literature ties the experience of socioeconomic disadvantage in childhood to early life cognitive delays and poorer cognitive function in adulthood (Evans & Schamberg 2009; Noble et al. 2007; Singh-Manoux et al. 2005; Singh-Manoux et al. 2004; Richards & Wadsworth 2004). However, the effects of early life conditions on long-term cognitive outcomes are far from deterministic. Those from disadvantaged backgrounds vary greatly in their cognitive health, with some experiencing delayed cognitive development and worsening cognitive performance in adulthood, and others appearing to be largely resistant to the negative impacts of early disadvantage on cognitive health (Masten, Best, & Garmezy 1990; Windle 2011). A better understanding of the individual differences that contribute to differential cognitive health outcomes is necessary to identify those at the greatest risk for cognitive impairment and dementia, and has the potential to identify ways to mitigate cognitive health disparities in adulthood.

Personality characteristics may be one domain of inter-individual variation that shapes how people respond to and ultimately emerge from early life disadvantage. Conscientiousness in particular, defined by the tendency to think and behave in careful, goal-directed ways, has the potential to confer greater cognitive resilience in the face of social adversity (Wilson et al. 2007; Wilson et al. 2015; Jackson, Balota, & Head 2009). Conscientiousness is thought to be partially heritable and partially developed through environmental influences, such as nutrition, learned behaviors, and parenting practices, which suggests that the development of conscientious personality traits in early life is at least partially modifiable (Jang, Livesley, & Vemon 1996; Luciano et al. 2006; Bouchard & McGue 2003). Conscientious individuals display greater self-control and discipline, propensity for planning, orderliness, and rule following (Shanahan et al. 2014; Roberts et al. 2014). These characteristics are linked to health-promoting behaviors, greater educational and occupational attainment, etc. that are collectively thought to produce better physical health outcomes (Shanahan et al. 2014). However, less attention is given to the role of conscientious in shaping cognitive health, as well as the ways in which conscientiousness interacts with social contexts to shape cognitive outcomes across the life span.

To address these research gaps, the present research intersects approaches to the life course and health disparities to examine how early life socioeconomic disadvantage and conscientiousness interact to shape midlife cognitive outcomes. Second, this work identifies how the interaction between early life socioeconomic disadvantage and conscientiousness varies by age. Finally, I test socioeconomic, behavioral, and psychosocial mechanisms that explain how the interaction between early life socioeconomic disadvantage and conscientiousness shapes cognitive outcomes. Collectively, this research examines how the intersection of early life socioeconomic context and personality predicts long-term cognitive function, which has important implications for targeting those at risk of poor cognitive health in adulthood.

The Long Arm of Childhood: Early Life Disadvantage and Midlife Cognitive Function

Early life disadvantage has a profound impact on the cognitive health of individuals (Singh-Manoux et al. 2005; Singh-Manoux et al. 2004; Richards & Wadsworth 2004). Children from disadvantaged households are often deprived of material and psychosocial resources that are crucial for brain development, and given that childhood is a sensitive period for these developmental processes, the effects of early life contexts on the brain have the potential to last into adulthood to ultimately affect cognitive function (Ben-Shlomo & Kuh 2002; Keating 2004). Studies building on Hayward and Gorman's conceptualization of "the long arm of childhood" have identified the significant associations between early life socioeconomic conditions and late life cognitive function and decline (Luo & Waite 2005; Singh-Manoux et al. 2004; Richards & Wadsworth 2004). However, midlife is often neglected in this area of research. Exploration of how early life socioeconomic conditions shape midlife cognitive outcomes would provide the opportunity to identify at-risk individuals who experience the onset of cognitive decline before late life. We conceptualize midlife as a stage when the maintenance of cognitive functioning is ideal; however, early signs of cognitive aging may already be apparent in this life stage among those at higher risk of dementia. Differential experiences of deprivation and stress by socioeconomic status may be an important determinant of inter-individual differences in cognitive aging. It is possible that those from disadvantaged socioeconomic environments are at greater risk of earlier-onset cognitive decline than those in more advantaged conditions, thus identifying these at-risk groups early would enable preventative measures to be applied before more clinical declines accumulate in old age (Aldwin & Levenson 2001; Schaie 2000).

Conscientiousness as a Mechanism for Cognitive Resilience

While early life socioeconomic disadvantage is predictive of lower cognitive function relative to those with no experience of disadvantage, lower cognitive function is not ubiquitous among those who grew up in disadvantaged households. In other words, some appear to be more prone to the negative impacts of disadvantage than others, and the sources of this inter-individual variation are poorly understood. Personality characteristics, particularly the protective effect of conscientiousness, might contribute to this heterogeneity. Conscientiousness is defined by the tendency to think in careful, goal-directed ways, thus displaying greater self-control, orderliness, and rule following (Wilson et al. 2007; Wilson et al. 2015; Jackson, Balota, & Head 2009; Shanahan et al. 2014). Conscientiousness confers better outcomes across an array of social, psychological, and physical domains, including status attainment, lower risk of mental illness, and better physical health (Hampson et al. 2007; Roberts et al. 2007; Gelissen & de Graaf 2006; Hampson et al. 2013). Specific to cognitive outcomes, higher conscientiousness is associated with better short-term memory, visual and auditory processing, slower rates of cognitive decline in old age, and lower incidence of Alzheimer's dementia and mild cognitive impairment (Wilson et al. 2007; Chapman et al. 2012; Baker & Bichsel 2006).

Conscientiousness has the potential to protect against the adverse health effects of disadvantage. Put forth by Shanahan and colleagues (2014), the Life Course Personality (LCP) model considers the ways in which personality (particularly conscientiousness) intersects with social context and stage of the life course to shape health outcomes. In other words, conscientiousness might have stronger associations with health in some contexts and during some life stages compared to others. While the LCP model does not explicitly consider cognitive outcomes, similar risk and protective factors based on conscientiousness likely shape both physical and cognitive health, such as exposure to and management of stressors, health behaviors, and symptom management.

Expanding on the LCP model, the association between early life disadvantage and adult cognitive function might vary depending on one's level of conscientiousness. Conscientious individuals have a higher propensity to engage in behaviors that promote cognitive health, such as community engagement, physical activity, and stress management, and a lower propensity to engage in risk behaviors such as cigarette smoking and delinquency. With this perspective in mind, I propose that higher conscientiousness buffers against the negative effects of early life disadvantage. In other words, the association between early life disadvantage and adult cognition might be weak or non-existent among those who express high conscientiousness, while the negative association between disadvantage and cognition might be stronger among those with low conscientiousness. Alternatively, it is possible that early life disadvantage and conscientiousness have additive (and not interactive) associations with cognitive function. In other words, individuals could differ in cognitive function based on socioeconomic background, and conscientiousness could offer cognitive benefits, but the degree of cognitive benefit by conscientiousness will be the same for everyone, regardless of socioeconomic background.

Lasting Impacts of Early Life Disadvantage and Conscientiousness

In addition to considering how social contexts moderate the relationship between conscientiousness and cognitive function, the LCP model also considers how conscientiousness shapes health differently across different stages of the life course. In other words, conscientiousness might be more protective in some life stages than in others. Taking this a step further, I consider the ways in which the interaction between social context and conscientiousness vary by age.

In describing the LCP model, Shanahan and colleagues consider several hypotheses for the ways in which the relationship between conscientiousness and health varies by age. First, aligned with *cumulative advantage theory*, the benefits of conscientiousness might cumulatively impact health across time as the benefits of conscientious attitudes and behaviors continue to accrue. Therefore, observation of divergent age trajectories by levels of conscientiousness would support cumulative advantage. Conversely, the *age-as-leveler hypothesis* suggests that the protective effects of conscientiousness on health would diminish from midlife to old age, or converge with age. Evidence for age-as-leveler might mean that the health benefits of conscientiousness weaken with age because the natural aging process undermines any protective effects of personality. On the other hand, evidence for age-as-leveler could indicate selective mortality among older study participants, whereby those who are least conscientious die younger to create the illusion of convergence with age.

Extending these hypotheses to consider age variation in the interaction of early life socioeconomic disadvantage with conscientiousness to predict cognition, one might expect to observe either cumulative advantage or age-as-leveler among those from various socioeconomic backgrounds. Figure 3-1 illustrates how support for cumulative advantage and age-as-leveler hypotheses would look when we assess only those from disadvantaged backgrounds. With cumulative advantage, one would observe that conscientiousness continues to minimize the negative impacts of early life disadvantage across the life span, with protective effects accumulating with age. Conversely, with age-as-leveler, the protective effects of conscientiousness against early life disadvantage diminish from midlife to old age. This could be due to the aging process in undermining the protective effects of conscientiousness, or to the selective mortality of those who are less conscientious and/or from more disadvantaged backgrounds.

Mediating Mechanisms

Higher conscientiousness is likely to alter the associations between early life socioeconomic disadvantage and adult cognitive function via social, psychological, and behavioral mechanisms. First, social relationships in early life could influence both the development of conscientiousness and cognitive outcomes, and are thus important confounders to include in the analysis. For example, parenting practices, including parental warmth, are thought to positively influence the development of conscientiousness in childhood and adolescence (Heaven & Ciarrochi 2008; McCrae & Costa 1988) and also foster cognitive development (Estrada et al. 1987; Farah et al. 2008). In addition, conscientious individuals are more likely to acquire higher educational and occupational attainment than those who are less conscientious (Hampson et al. 2007; Lleras 2008), thus influencing access to cognitively stimulating resources. More conscientious individuals are also more likely to be socially integrated and to seek social support in the face of stress than those of lower conscientiousness (Hill et al. 2012; Vollrath & Togersen 2000). Social integration has been shown to be protective against adult cognitive decline (Zunzunegui & Alvarado 2003; Seeman et al. 2001). Therefore, more conscientious individuals might be better able to combat the negative effects of early life socioeconomic disadvantage on cognitive outcomes through stronger social connections.

Conscientious individuals also experience better psychological wellbeing, which could buffer against the negative influences of early life disadvantage on cognitive function. Conscientiousness is associated with lower risk of depression and faster recovery from depression (Anderson & McLean 1997; Hayward et al. 2013). Depression is also associated with lower cognitive function (Brown et al. 1994; Tarbuck & Paykel 1995). Finally, conscientious individuals have greater self-efficacy, which positively influences educational achievement (Caprara et al. 2010; Moffitt et al. 2011). These characteristics could protect against the negative cognitive outcomes of early life disadvantage by promoting resilience in the face of adversity.

Finally, conscientious individuals participate in more health-promoting behaviors and fewer health-risk behaviors, resulting in both physical and cognitive health gains. Those from more disadvantaged settings are more likely to engage in health-risk behaviors, including poor diet, physical inactivity, and cigarette smoking (Pampel & Krueger 2010). Conscientiousness, on the other hand, is positively associated with healthy eating and regular physical activity, and is negatively associated with cigarette smoking (Bogg & Roberts 2004). These health behaviors are also associated with better cognitive function (Sabia et al. 2009; Cotman & Berchtold 2002), making health behaviors a plausible mechanism through which more conscientious individuals from disadvantaged settings have better cognitive outcomes than those of lower conscientiousness.

The Present Study

Building on prior theoretical and empirical developments, the present study tests how the interaction of early life socioeconomic conditions, conscientiousness, and age shapes adult cognitive function. I test three specific research questions. First, does conscientiousness moderate the association between early life socioeconomic conditions and adult cognitive function? Second, does the moderating effect of conscientiousness on the association between early life socioeconomic conditions and cognitive function vary by age? Third, what social, psychological, and behavioral processes explain these links? Insight into the ways in which social contexts and personality combine across the life course to predict adult cognitive outcomes will shed light on the complex determinants of cognitive health, and will aid in identifying who is most at risk of the negative impacts of early life disadvantage.

Data

The data come from the National Survey of Midlife Development in the U.S. (MIDUS; 1995-2006), a national sample of 7,108 adults (N for both the SAQ and phone survey?) age 25-74 at baseline. Initial data collection was administered through random digit dialing (RDD) telephone surveys, with additional data collected from 6,329 respondents through self-administered questionnaires (SAQs). Follow-up assessments were administered 10 years after the initial data collection, with a retention rate of 64% for both the phone survey and SAQ. Among the 3,929 respondents with phone surveys and SAQs for both study waves, 585 had missing cognitive data and 759 had missing socioeconomic, psychosocial, or behavioral data used in the analysis. My sample consists of N=2,585 respondents who participated in both the phone surveys and SAQ in both study waves, and who had complete data for the variables of interest.[2]

[2] I did not conduct multiple imputation because the majority of missing data was due to missing SAQs. Therefore, most missing data was due to survey missingness rather than item missingness. Sensitivity analysis using respondents with complete data for childhood disadvantage, conscientiousness, cognitive function, and basic demographic characteristics (N=3,187) revealed no difference in the interaction models compared to the analytic sample (N=2,585).

Measures

Cognitive Function

During Wave II of MIDUS, cognitive function was assessed using the Brief Test of Adult Cognition by Telephone (BTACT), which consists of seven cognitive tasks that gauge functioning in working memory, executive function, reasoning, and processing speed (Lachman, Tun, & Murphy 2009; Tun & Lachman 2006). These tasks include the immediate and delayed word recall, digits backward, number series completion, category fluency, backward counting, and two scores from the stop-go-switch task. I created a *cognitive function index* by dividing each memory task by the highest possible score within that task, creating seven continuous items ranging from 0-1 (for example, the immediate word recall task ranges from 0-15, so dividing by 15 will produce a scale from 0-1). I then summed these seven rescaled scores to produce a continuous cognitive function index with a possible range of 0-8. Further information about the administration and coding of these cognitive tasks can be found in Ryff & Lachman (2009).

Socioeconomic Disadvantage

An index of *early life socioeconomic disadvantage* was constructed using four indicators of disadvantage retrospectively reported by MIDUS respondents in wave I. These four binary indicators include 1) parent education (less than high school), 2) ever receiving welfare as a child, low subjective childhood SES, and low parent SEI (socioeconomic index; see Brim, Ryff, & Kessler 2004). Summing these four indicators produced an index ranging from 0-4, with higher scores indicating higher disadvantage.

Conscientiousness

A continuous index of *conscientiousness* was constructed using a subset of items from the Midlife Development Inventory (MIDI) Personality Scales at wave II. Respondents were asked how well certain characteristics described them, with response categories including “a lot,” "some," "a little," and "not at all." Five items were used to gauge conscientiousness, including whether respondents considered themselves organized, responsible, hardworking, careless (reverse coded), and thorough. A continuous conscientiousness index was constructed by taking the mean of the five conscientiousness items, producing a score ranging from 1-4.

Age

Age was measured at wave II and ranged from 33-84. In addition to modeling age as a continuous variable, stratified samples by age group were used to capture those in early-middle age (55 and under) and later-middle age (over age 55).

Underlying Mechanisms

I tested several mechanisms that potentially explain the interrelationships between early life socioeconomic disadvantage, conscientiousness, and cognitive function. These include maternal relationship during childhood, status attainment, social integration, locus of control, mental health, and physical health status and behaviors. First, I tested for respondent perceptions of maternal relationship during childhood. Maternal warmth and closeness has the potential to shape the development of both conscientiousness and cognitive ability of the respondent. *Maternal warmth* was measured using respondents' retrospective accounts of their mothers' parenting practices, including whether the mother gave time and attention when needed, made sure the respondent had a good upbringing, taught the respondent about life, did the best she could as a parent, was a model of generosity, and was someone the respondent could confide in. *Relationship with mother* was measured using a single item in which respondents were asked to "rate your relationship with your mother during the years you were growing up." Four measures of *status attainment* were tested as possible mechanisms: respondent educational attainment, household income, household assets, and occupational status/prestige. *Social integration* was measured using seven indices of integration, including frequency of family, friend, and neighbor contact, volunteer work, marital status, social activities, and religious attendance. *Locus of control* was tested across three domains: perceived control, health control, and cognitive. Perceived control was constructed using 12 items of mastery and perceived constraints, such as "What happened in the future mostly depends on me" and "I have little control over the things that happen to me" (reverse coded). Health locus of control was measured using four items related to attitudes and behaviors about health, such as "Keeping healthy depends on the things that I do." Cognitive locus of control was measured using nine items from the Personality in Intellectual Aging Contexts (PIC) scale. The PIC scale captures attitudes and behaviors related to control over cognitive aging, such as "It's inevitable that my intellectual functioning will decline as I get older" and "There's not much I can do to keep my memory from going down hill." Two domains of *mental health* were measured, including depressive symptoms and anxiety symptoms. Finally, *health status and behaviors* was measured using several items: body mass index, waist-to-hip ratio, cigarette smoking, physical activity, and average hours of sleep per night.

Analysis

I conducted ordinary least squares (OLS) regressions to test the associations of childhood socioeconomic disadvantage, conscientiousness, and adult cognitive function. Models tested for bivariate associations of childhood disadvantage and conscientiousness with cognitive function separately, followed by a combined model to test for additive associations. Next, I tested for the interaction of childhood disadvantage with conscientiousness to predict adult cognition. Finally, I included a three-way interaction to determine whether the interaction between childhood disadvantage and conscientiousness varies by age. All models were adjusted for sex and race/ethnicity and accounted for clustering by family.[3]

In addition to moderation models, I tested for mechanisms that potentially mediate the interaction of early life disadvantage with conscientiousness among those in midlife and among older adults. These models were conducted in a stepwise fashion in order to first test for each cluster of mediators separately (that is, maternal warmth and relationship, status attainment, social integration, locus of control, mental health, and physical health), followed by a full model that adjusted for all mediators.[4]

Results

Table 3-1 shows descriptive statistics for the analytic sample, along with differences in the variables of interest by cognitive function and conscientiousness. Bivariate regressions show that conscientiousness is positively associated with cognitive function, while childhood disadvantage is negatively associated with cognitive function and has no association with conscientiousness. Age is negatively associated with cognitive function but has no association with conscientiousness. Females score higher on both cognitive function and conscientiousness. Although whites score significantly better on the cognitive task, there are no significant race differences in conscientiousness. Maternal warmth and relationship is positively related to adult conscientiousness, but has no association (and possibly a negative association) with cognitive outcomes.

[3] Sampling weights were not available for about half of the sample and were therefore not implemented in the analysis.

[4] Additional analyses tested whether each of the mechanisms differ by age by interacting each item with age in the regression model. No significant age variation in the associations between mechanisms and cognitive function were observed.

As expected, those with lower educational attainment tend to score lower on both conscientiousness and cognition, while those with higher educational attainment tend to score higher on both. Income is positively associated with both cognitive function and conscientiousness, while assets are positively associated with conscientiousness but not with cognitive function. Further, low occupational prestige is associated with both lower conscientiousness and cognitive function, while higher occupational prestige is positively associated with both. Those who are more socially integrated and who report higher locus of control have higher average conscientiousness and cognitive function, while depression is associated with lower conscientiousness but not lower cognitive function. Health behaviors follow the expected patterns: higher body mass index, higher waist-to-hip ratio, and being a cigarette smoker are associated with lower conscientiousness and cognitive function. Finally, regular physical activity is associated with higher conscientiousness and cognitive function.

Table 3-2 shows the OLS results for the additive and interactive associations of childhood disadvantage and conscientiousness with adult cognitive function. Model I shows the association of childhood disadvantage with adult cognition when adjusting for age, sex, and race/ethnicity, and reveals that a one-unit increase in childhood disadvantage is associated with .1 point reduction in adult cognitive function. Model II shows the association of conscientiousness with adult cognitive function, and identifies that a one-unit increase in conscientiousness is associated with a .13 increase in the cognitive function score. When both childhood disadvantage and conscientiousness are modeled simultaneously in Model III, little attenuation is observed for both estimates, suggesting that childhood disadvantage and conscientiousness are independent predictors of adult cognitive outcomes. Model IV tests for the interaction of childhood disadvantage and conscientiousness in predicting cognitive outcomes, and shows no significant interaction. However, inclusion of a three-way interaction between childhood disadvantage, conscientiousness, and age in Model V reveals that the interaction between childhood disadvantage and conscientiousness varies by age.

Figure 3-2 depicts age differences in the interaction between childhood disadvantage and conscientiousness by stratifying the sample into middle adult (<=55 years) and later adult (>55 years) subsamples. The figure shows a significant interaction between childhood disadvantage and conscientiousness in the middle adult sample, whereby those who exhibit greater conscientiousness appear to be buffered from the poorer cognitive outcomes associated with childhood disadvantage, while those who score low on conscientiousness have poorer cognitive outcomes as childhood disadvantage increases. However, the same pattern is not observed for the over 55 subsample. In fact, the effect of conscientiousness on cognitive function appears to be greatest among those who are did not experience childhood disadvantage; however, this differences is not statistically significant.

Table 3-3 shows estimates for the potential mechanisms explaining the interaction of early life socioeconomic disadvantage and conscientiousness among those age 55 and under.[5] Results show weak evidence for mediation across the mechanisms tested. Model I shows the baseline model with no mechanisms for the younger subsample. The significant interaction term of 0.10 means that the higher the value of early life disadvantage, the greater the association of conscientiousness with cognitive function, suggesting that conscientiousness plays a stronger role in shaping cognitive outcomes among those from disadvantaged backgrounds. Model II includes measures of maternal relationship and warmth. While maternal warmth is positively

[5] Mediation analysis was also conducted on the full sample to determine whether mechanisms explained the three-way interaction between early life socioeconomic disadvantage, conscientiousness, and continuous age. No mediation was found in this analysis.

associated with cognitive function, there is no attenuation in the estimate for the interaction term, suggesting that maternal warmth is independently associated with cognitive outcomes. Model III includes status attainment, and shows that respondent educational attainment and occupation (as indicated by the socioeconomic index) both predict cognitive function. There is slight attenuation in the interaction term (from coef.=0.10, $p<0.05$ to coef.=0.09, $p<0.1$), suggesting partial mediation. Model III also has a dramatic increase in model fit, suggesting that status attainment is a strong predictor of cognitive function. Model IV includes social integration. While social integration is positively associated with cognitive function, no mediation is observed. Similar results are shown in Models V-VII, which separately adjust for locus of control, mental health, and physical health. While cognitive locus of control, depressive symptoms, waist-to-hip ratio, cigarette smoking, and physical activity all predict adult cognitive function, inclusion of these items does not reduce the interaction term between early life disadvantage and conscientiousness. Model VIII is the fully adjusted model that includes all mechanisms of interest. Respondent educational attainment, social integration, cognitive locus of control, waist-to-hip ratio, and physical activity continue to be significantly associated with cognitive function; however, these items only explain a small portion of the interaction between early life disadvantage and conscientiousness (coef.=0.09, $p<0.1$). Overall, these results do not fully explain the moderating effect of conscientiousness on the association between early life disadvantage and adult cognitive function.

Discussion

Using a longitudinal sample of U.S. adults spanning from midlife to old age, the present study tests the links between early life socioeconomic disadvantage, conscientiousness, and cognitive function across the life span. Results indicate that the association between early life socioeconomic disadvantage and cognitive function varies by conscientiousness, such that those who are more conscientious are more cognitively resilient in the face of early life adversity. However, this relationship varies by age: conscientiousness is found to protect against the negative cognitive impacts of early life disadvantage among those in middle age, but these protective effects are not observed among older adults. Though not included in this study, other domains of the big five personality characteristics (openness, extraversion, agreeableness, and neuroticism) did not significantly moderate the association of early life disadvantage with adult cognitive function. Finally, while status attainment, mental health, and physical health appear to partially mediate the interaction of early life disadvantage and conscientiousness among middle-aged adults, more remains to be explained.

This work sheds new light on the ways in which social context and personality intersect to shape cognitive outcomes. People from disadvantaged family backgrounds are more prone to physical and cognitive health problems across the life span, making them a target for interventions aimed at improving public health. Extrapolating from these results, it appears that among those from disadvantaged backgrounds, those at the greatest risk of poorer cognitive outcomes are individuals who display lower conscientiousness. On the other hand, those with higher conscientiousness appear to be largely protected from the negative cognitive outcomes associated with disadvantage, at least through midlife. By later adulthood, however, the cognitive benefits of conscientiousness among those from disadvantaged backgrounds have largely dissipated. This finding provides evidence for the *age-as-leveler hypothesis*, such that conscientiousness is only protective at younger ages and has no protective effect in late life.

There are several possible reasons for support for the process of age-as-leveler. First, protective personality traits might play less of a role in promoting cognitive resilience by late life, as the inevitable biological effects of aging mask the benefits of protective attitudes and behaviors. In other words, biological aging might undermine the social, behavioral, and psychological factors that stave off cognitive decline in midlife. Alternatively, it is possible that selective mortality contributes to the weakening in the association between early life disadvantage, conscientiousness, and cognitive function. One would expect that those from disadvantaged backgrounds, those who are less conscientious about their health, and those with poorer cognitive health are at greater risk of early mortality and are therefore under-represented in the older subsample. However, it is unclear how these selective mortality patterns would affect those from disadvantaged backgrounds who express high levels of conscientiousness, or those from more advantaged backgrounds who express low levels of conscientiousness. Use of longitudinal studies that span early life and adulthood would provide greater insight into the ways in which mortality patterns influence these relationships.

These findings have important implications for health disparities research and policy. The finding that conscientiousness modifies the association between socioeconomic conditions and cognitive function emphasizes the need for sociologists to consider how psychological processes and personal dispositions complicate the links between social exposures and individual health and wellbeing. Indeed, the ways in which individuals are affected by social circumstances differs depending on the ways in which these conditions are interpreted and acted on. Individual attitudes and behaviors belonging to particular personality characteristics offer one way to observe how individuals interact with environments to shape life trajectories.

The results of these analyses also suggest another important question: where does conscientiousness come from? Can conscientiousness be cultivated in early life, thus providing disadvantaged youth with some of the characteristics that improve chances for upward mobility and cognitive resilience? Or on the other hand, is conscientiousness largely biologically determined and therefore fixed at birth? The answer likely lies somewhere in the middle, meaning that early life educational and family interventions that foster conscientiousness might be one avenue to promote cognitive resilience across the life span. However, given that the mean for cognitive function was highest among those who were not from disadvantaged backgrounds *regardless* of conscientiousness, a more effective intervention strategy would be to mitigate early life inequalities to promote cognitive development regardless of personality. Further research is needed to examine these research questions.

It is important to note that evidence supporting the role of conscientiousness in buffering the negative impacts of early life disadvantage does not mean that those who are unable to mobilize out of disadvantage lack the drive to succeed, or that those who are less conscientious should be blamed for their poor physical and cognitive health. Rather, it is important to consider that in contexts of deprivation, the effort required to mobilize in terms of cognitive health is much greater than what is required of those from more advantaged settings. Only adults with the highest expression of conscientiousness are able to achieve cognitive functioning that is equivalent to those who are not disadvantaged, while conscientiousness does not appear to play a role in shaping cognitive outcomes among those from more advantaged backgrounds. Therefore, the onus is not on disadvantaged individuals to develop more conscientious habits, but rather on socioeconomic structures that put many at greater risk of poorer physical and cognitive health.

This research has several limitations that should be addressed in future work. First, these results are correlational and do not definitively identify causal relationships between disadvantage, conscientiousness, and cognitive function. For instance, it is possible that higher cognitive abilities shape conscientious, and higher conscientiousness ultimately enables mobility out of disadvantage. Because my observation of both conscientiousness and cognitive function take place at a single time point in adulthood, I am unable to follow the development of conscientiousness and cognitive function from early life into adulthood. Further, though conscientiousness and cognitive function are interrelated, the precise ways in which they operate together remain unclear. For example, in contrast to the prevailing view that conscientiousness and cognition are positively correlated, a smaller yet significant area of research notes that some forms of intelligence are actually negatively associated with conscientiousness (Moutafi, Furnham, & Paltiel 2004; Ackerman & Heggestad 1997; Chamorro-Premuzic and Furnham 2005; DeYoung 2011). More research is needed to understand the complex interrelation between conscientiousness and cognitive abilities. In addition, longitudinal measurement of conscientiousness and cognitive function across early life and adulthood would strengthen causal inferences.

In conclusion, conscientiousness is an important personality domain that should be considered when examining the ways in which early life contexts shape individual outcomes. These topics should also be explored using a life course framework that considers the ways in which social conditions and personality shape health and wellbeing differently depending on the life stage examined. Just as many of the social constructs we examine have dynamic and distinct influences on individual outcomes depending on the timing in which they are experienced, personality characteristics have differing impacts on individuals depending on the ways in which personality interacts with one’s age. A cross-disciplinary view that considers both social and psychological processes in shaping complex health outcomes such as cognitive function is necessary to make advances in mitigating cognitive health disparities.

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***Table 3-1**. Descriptive Statistics: National Survey of Midlife Development in the U.S. (N=2,585)*

Variable	Mean (SD) or %	Diff. by Cognitive Function?	Diff. by Conscientious?
Cognitive function	4.7 (0.7)	N/A	+
Childhood socioeconomic disadvantage	0.8 (0.9)	-	NS
Conscientiousness	3.4 (0.4)	+	N/A
Age	55.4 (11.8)	-	NS
Female	53.2	+	+
Race/ethnicity			
White	93.5	+	NS
Black	2.4	-	NS
Hispanic	2.6	-	NS
Other	1.6	NS	NS
Relationship with mother	3.8 (1.1)	-	+
Maternal warmth	3.2 (0.6)	NS	+
Educational attainment			
Less than high school	4.2	-	-
High school graduate	26.2	-	NS
Some college	29.5	-	NS
College graduate or more	40.1	+	+
Household income	76006.4 (59615.8)	+	+
Household assets	1468.6 (2276.2)	NS	+
Occupational status/prestige			
Low prestige	14.1	-	-
Middle prestige	34.6	+	+
High prestige	17.4	+	NS
Unemployed	2.4	NS	NS
Retired	23.4	-	NS
Not in labor force	8.2	NS	-
Social integration	12.7 (2.7)	+	+
Perceived control	5.6 (1.0)	+	+
Health locus of control	6.1 (0.8)	NS	+
Cognitive locus of control	5.0 (0.9)	+	+
Depressive symptoms	0.6 (1.7)	NS	-
Anxiety symptoms	0.1 (0.7)	NS	NS
Body mass index	27.9 (5.6)	-	-
Waist/hip ratio	0.9 (0.1)	-	-
Currently smokes cigarettes	14.0	-	-
Vigorous physical activity			
None	22.8	-	NS
Less than once a week	40.0	+	-
Once a week	10.8	+	NS
Several times a week	26.4	+	+
Average hours of sleep	7.0 (1.1)	NS	NS

Note: Columns 4 and 5 indicate significant differences in variables of interest by cognitive function and conscientiousness, respectively. Differences were tested using bivariate OLS regression. +=positive association; -=negative association; NS=not significant; N/A=not applicable. α=0.05.

Table 3-2. *Associations of Early Life Disadvantage with Adult Cognitive Function by Conscientiousness and Age (N=2,585)*

	I	II	III	IV	V
Early life disadvantage	-0.10***		-0.09***	-0.26*	-1.80***
	(0.02)		(0.02)	(0.12)	(0.53)
Conscientiousness		0.13***	0.12***	0.08+	-0.28
		(0.03)	(0.03)	(0.04)	(0.18)
Age	-0.02***	-0.02***	-0.02***	-0.02***	-0.05***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
Early life disadvantage x conscientiousness				0.05	0.47**
				(0.03)	(0.16)
Early life disadvantage x age					0.03**
					(0.01)
Conscientiousness x age					0.01*
					(0.00)
Early life disadvantage x conscientiousness x age					-0.01**
					(0.00)
Female	0.05+	0.03	0.04	0.04	0.04
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Race/ethnicity (ref. White)					
Black	-0.59***	-0.63***	-0.60***	-0.60***	-0.60***
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Hispanic	-0.17+	-0.21*	-0.18+	-0.18+	-0.17+
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Other	-0.15	-0.16	-0.15	-0.15	-0.14
	(0.10)	(0.11)	(0.10)	(0.10)	(0.11)
Constant	6.09***	5.64***	5.68***	5.82***	7.14***
	(0.07)	(0.13)	(0.13)	(0.16)	(0.62)
R-squared	0.18	0.17	0.18	0.18	0.19

Standard errors in parentheses
*** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$

Table 3-3. *Underlying Mechanisms among Adults 55 and Under (N=1,348)*

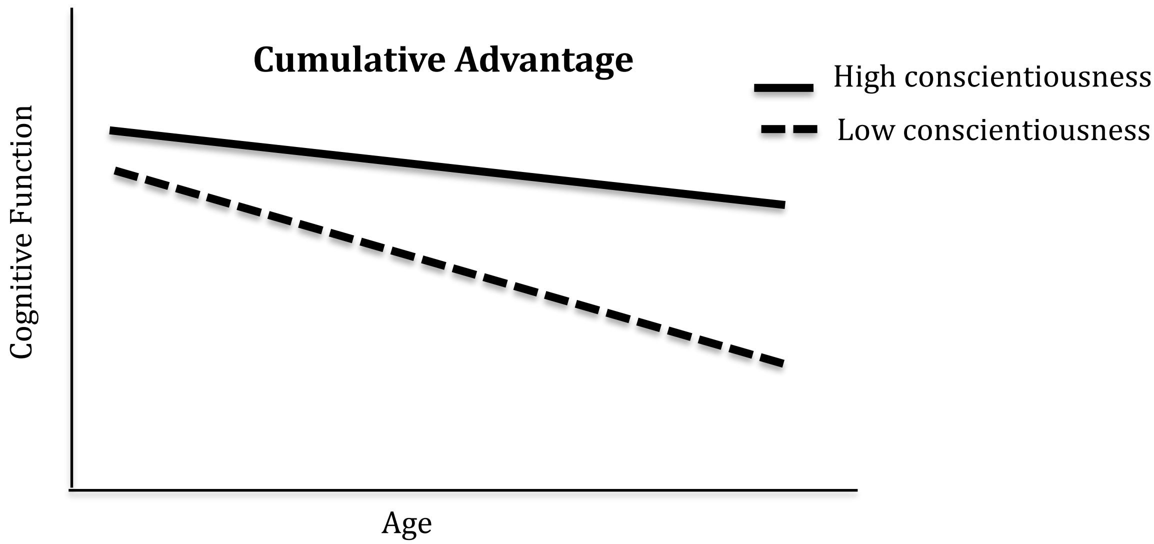
	I	II	III	IV	V	VI	VII	VIII
Early life disadvantage	-0.45*	-0.44*	-0.31+	-0.43*	-0.42*	-0.44*	-0.43*	-0.30+
	(0.18)	(0.18)	(0.16)	(0.18)	(0.17)	(0.18)	(0.18)	(0.16)
Conscientiousness	0.02	0.01	-0.02	0.02	-0.06	0.01	0.00	-0.06
	(0.06)	(0.06)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.05)
Early life disadvantage x conscientiousness	0.10*	0.10+	0.09+	0.10*	0.10*	0.10+	0.10+	0.09+
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
Female	0.03	0.03	0.08*	0.02	0.06	0.05	-0.03	0.05
	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Age	-0.01***	-0.01***	-0.02***	-0.02***	-0.01***	-0.01***	-0.01***	-0.01***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Race/ethnicity (ref. White)								
Black	-0.57***	-0.58***	-0.59***	-0.57***	-0.59***	-0.57***	-0.55***	-0.59***
	(0.13)	(0.13)	(0.11)	(0.13)	(0.12)	(0.13)	(0.12)	(0.11)
Hispanic	-0.29*	-0.28*	-0.23+	-0.27*	-0.29*	-0.29*	-0.25*	-0.22*
	(0.13)	(0.12)	(0.12)	(0.13)	(0.12)	(0.13)	(0.12)	(0.11)
Other	-0.18	-0.17	-0.24*	-0.16	-0.18	-0.17	-0.15	-0.20+
	(0.13)	(0.13)	(0.11)	(0.13)	(0.13)	(0.13)	(0.13)	(0.11)
Mother relationship		-0.03						-0.02
		(0.02)						(0.02)
Maternal warmth		0.09*						0.04
		(0.04)						(0.04)
Respondent education (ref. HS graduate)								
Less than HS			-0.18					-0.08
			(0.11)					(0.11)
Some college			0.19***					0.14**
			(0.05)					(0.05)
College or more			0.49***					0.42***
			(0.05)					(0.05)
Respondent household income			0.00					0.00
			(0.00)					(0.00)
Respondent household assets			0.00					0.00
			(0.00)					(0.00)

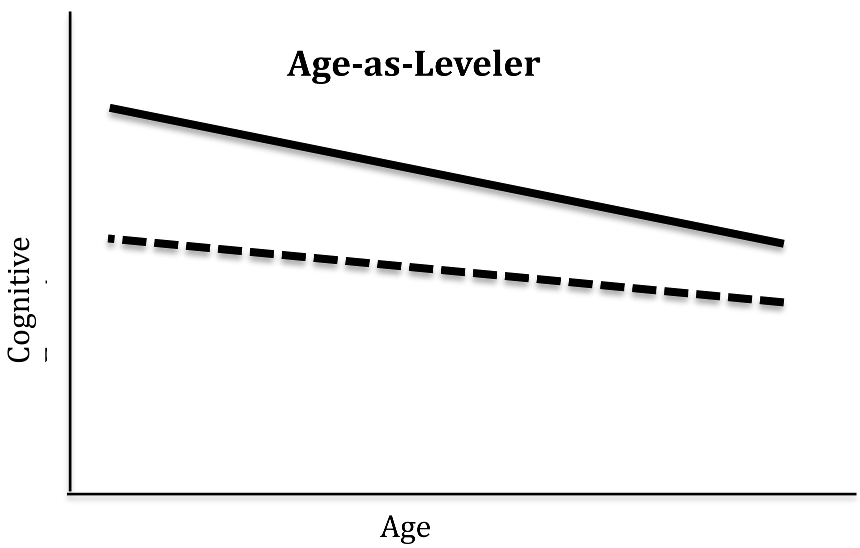
Socioeconomic index (ref. middle quartiles)						
Bottom quartile	-0.12*					-0.08
	(0.05)					(0.05)
Top quartile	0.09+					0.09+
	(0.05)					(0.05)
Unemployed	-0.16					-0.16
	(0.10)					(0.11)
Retired	-0.21					-0.13
	(0.15)					(0.15)
Not in labor force	-0.03					-0.04
	(0.06)					(0.06)
Social integration		0.04***				0.02**
		(0.01)				(0.01)
Perceived control			-0.01			-0.03
			(0.02)			(0.02)
Health locus of control			0.01			-0.01
			(0.02)			(0.02)
Cognitive locus of control			0.16***			0.11***
			(0.02)			(0.02)
CES-D depressive symptoms				-0.02*		-0.01
				(0.01)		(0.01)
Anxiety symptoms				-0.01		0.04+
				(0.02)		(0.02)
BMI					-0.00	0.00
					(0.00)	(0.00)
Waist/hip ratio					-0.59*	-0.43*
					(0.23)	(0.20)
Current smoker					-0.19***	-0.01
					(0.05)	(0.05)
Vigorous physical activity (ref. None)						
Less than once a week					0.26***	0.21***
					(0.06)	(0.05)
Once a week					0.23**	0.13*
					(0.07)	(0.07)

Several times a week							0.28***	0.17**
							(0.06)	(0.06)
Average hours of sleep							-0.02	-0.02
							(0.02)	(0.02)
Constant	5.51***	5.35***	5.30***	4.99***	4.90***	5.55***	6.09***	5.14***
	(0.23)	(0.26)	(0.21)	(0.24)	(0.25)	(0.23)	(0.36)	(0.36)
R-squared	0.06	0.07	0.20	0.09	0.11	0.07	0.10	0.24

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

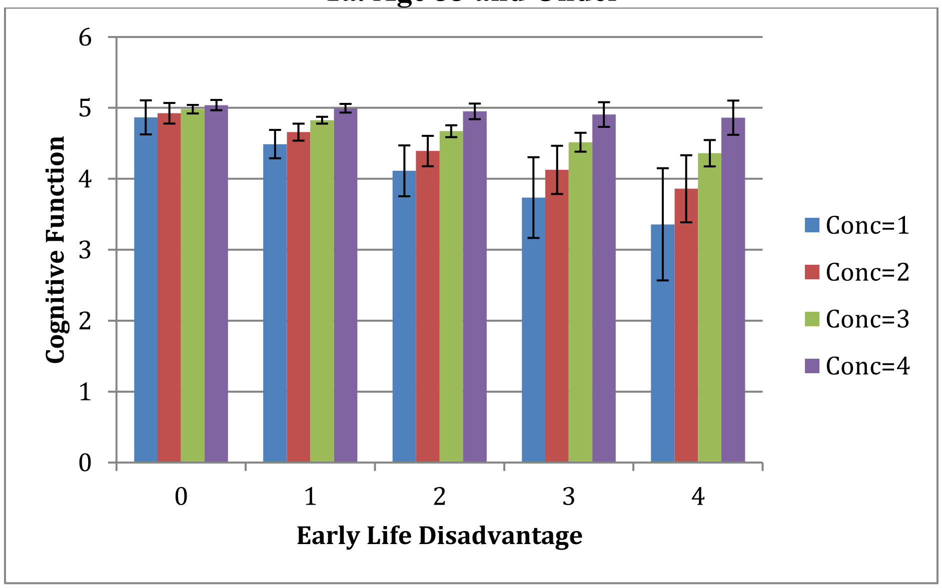
Figure 3-1. Hypotheses of Protective Effects of Conscientiousness with Age among those from Disadvantaged Backgrounds



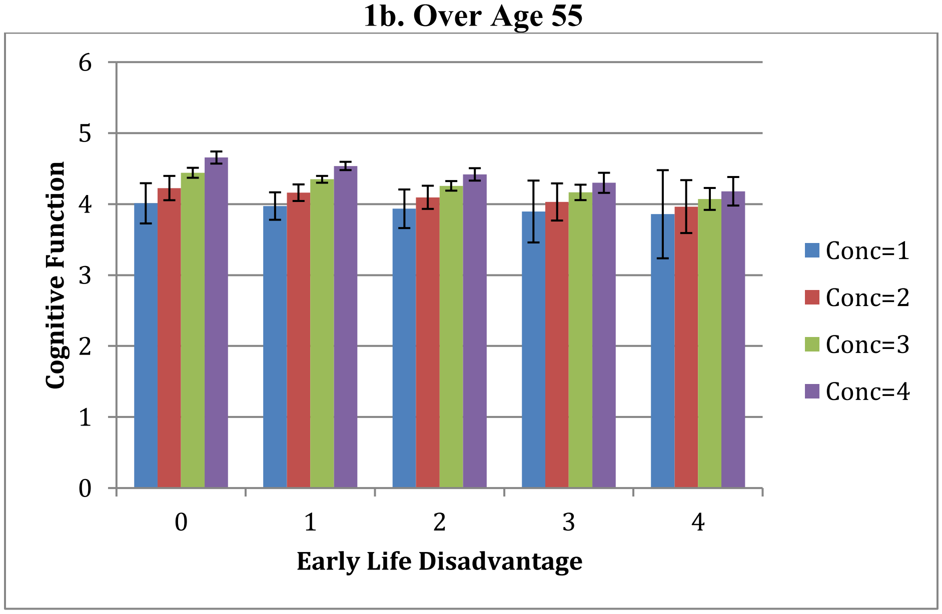


*<u>**Figure 3-2**. Differential Associations of Early Life Disadvantage with Cognitive Function by Level of Conscientiousness</u>*

1a. Age 55 and Under



1b. Over Age 55



CHAPTER FOUR: PATTERNS OF LATE LIFE COGNITIVE DECLINE: VARIATION ACROSS COHORTS AND SOCIOECONOMIC STATUS

Abstract

This study examines life course socioeconomic disparities in cognitive outcomes within and across birth cohorts. Using growth curve analysis of longitudinal data that spans 14 years, findings indicate significant inter-cohort heterogeneity in cognitive outcomes: while there were no cohort differences in mean cognitive function, significant cohort differences were found in age trajectories of cognitive decline, with more recent cohorts showing accelerated rates of cognitive decline. I also found significant intra-cohort socioeconomic disparities in cognitive outcomes. Both early life and adult socioeconomic disadvantage were negatively associated with cognitive function, especially parent and respondent education. Finally, there was significant inter-cohort variation in intra-cohort heterogeneity, with non-linear cohort differences in socioeconomic gaps in cognitive outcomes. These findings have implications for the macro-level social contributors to cognitive outcomes, and call for further research to understand declining cognitive outcomes among more recent cohorts.

Introduction

A growing literature finds that life course socioeconomic conditions predict late life cognitive function and decline (Cagney & Lauderdale 2002; Everson-Rose et al. 2003; Fors, Lennartson, & Lundberg 2009; Horvat et al. 2014; Lyu & Burr 2016). In particular, exposure to socioeconomic disadvantage across early life and adulthood is negatively associated with worse cognitive function (Fors, Lennartson, & Lundberg 2009; Horvat et al. 2014; Lynch et al. 1997) and more rapid cognitive decline (Lyu & Burr 2016) among older adults. Life course socioeconomic conditions have the potential to shape late life cognitive outcomes by affecting access to social and cognitive resources (such as complexity of work), exposure to stress, and adherence to health-related behaviors that are also important for maintenance of cognitive function (Andel et al. 2007; Brown 2010; Bassuk et al. 1999; Cotman & Berchtold 2002).

While the links between social conditions and cognitive aging have been extensively studied, little is known about whether the association between socioeconomic status and cognitive outcomes differs across birth cohorts. By ignoring the influence of cohort membership on cognitive outcomes, one implicitly assumes that all cohorts experience the same social conditions that shape patterns of cognitive function and decline. In addition, modeling age trajectories of cognitive decline using cross-sectional samples risks confounding age differences with cohort variations in cognitive outcomes (Yang & Land 2013). Indeed, preliminary evidence of cohort differences in late life cognitive outcomes suggests that different cohorts do have unique cognitive trajectories, demonstrating the need to consider cohort differences in order to better understand trends in cognitive health (Berg & Steen 1998; Christensen et al. 2013; Rowe & Kahn 1987; Schaie, Labouvie, & Buech 1973; Singh-Manoux et al. 2012).

Moreover, socioeconomic conditions and inequalities experienced in the U.S. have changed across historical time, and the unique socioeconomic experiences of birth cohorts might have different meanings for cognitive outcomes in late life. For example, among older adults in the U.S., more recent cohorts have higher educational and occupational attainment than older cohorts, which could contribute to better cognitive outcomes among younger cohorts (Berg & Steen 1998; Christensen et al. 2013). Conversely, more recent cohorts were also in the labor force during the Great Recession and an era of rapidly growing economic inequality, meaning that socioeconomic inequalities in cognitive outcomes could be most pronounced in these younger cohorts. Insight into the unique cognitive trajectories of these cohorts will improve understanding of the social exposures across the life span that contribute to cognitive health among older adults.

Building on these issues, the present study has three primary goals: 1) to examine inter-cohort variation in cognitive function and decline in young adulthood, 2) to test intra-cohort socioeconomic disparities in cognitive function and decline, and 3) to test whether intra-cohort disparities in cognitive function and decline vary across birth cohorts (in other words, inter-cohort variation in intra-cohort socioeconomic disparities in cognitive outcomes). In addition to distinguishing between age and cohort influences on late life cognitive outcomes, this research also incorporates multiple domains of socioeconomic disadvantage to capture SES exposures in across early life and adulthood, thus examining how longitudinal links between life course SES and cognitive outcomes differ across birth cohorts. Ultimately, this work aims to achieve greater understanding of the social structural factors that contribute to late-life cognitive outcomes.

Inter-Cohort Variations in Cognitive Function and Decline

Evidence across sociology, epidemiology, and neuroscience suggests that social conditions are important determinants of cognitive function and decline in late adulthood (Cagney & Lauderdale 2002; Everson-Rose et al. 2003; Fors, Lennartson, & Lundberg 2009; Horvat et al. 2014; Lyu & Burr 2016). While the majority of research on the social determinants of cognitive aging focuses on individual-level factors that contribute to cognitive outcomes, such as education or income, little attention has been given to how these individual-level factors are conditioned by macro-level social factors, such as opportunities for educational and occupational attainment or national-level income and wealth inequality. Further, these macro-level social factors are not fixed but rather shift across historical time. Therefore, one would expect that cohort membership, or year of birth, has significant implications for cognitive outcomes.

The life course perspective articulates that lives are structured by the interaction of individuals with broader social conditions across time (Elder, Johnson, & Crosnoe 2003). In addition, the *timing* of these interactions within individual lives matters. For example, in Glen Elder's seminal work titled *Children of the Great Depression*, he found that the age in which children experienced the Depression had a lasting influence on educational, occupational, and psychological outcomes (Elder 1999). This line of inquiry gives rise to the importance of birth cohort membership in shaping life trajectories, as the timing in which one is exposed to broader social structural factors has a lasting influence on life chances.

Each birth cohort experiences a unique constellation of experiences based on macro-level social conditions, such as economic prosperity or inequality, war, educational opportunities, and health care policies (Ryder 1965). These historical shifts could have significant implications for cohort differences in cognitive health. For example, the U.S. has had increasing mean levels of education across time, potentially leading to better cognitive outcomes among more recent cohorts. In addition, improvements in health care over the past century have potentially improved cognitive health among older adults. However, these health care improvements have also led to longer life expectancies, and thus higher population-level incidence of chronic conditions such as cognitive impairment and dementia (DeCarli 2003). Finally, income and wealth inequality have risen dramatically in the U.S., potentially leading to declines in cognitive function among more recent cohorts.

Previous research has found mixed results for inter-cohort differences in cognitive function and decline. While some have found that recent cohorts have higher cognitive function and slower rates of cognitive decline than previous cohorts (Berg & Steen 1998; Christensen et al. 2013; Rowe & Kahn 1987), other research has found no inter-cohort differences in cognitive outcomes after accounting for survey design and study attrition (Rodgers, Ofstedal, & Herzog 2003; Hulur et al. 2013). However, these studies often rely on two or three cohorts and several waves of data. Inclusion of more adult cohorts across multiple waves could provide additional insights into cohort variation in cognitive outcomes.

Socioeconomic Disparities in Cognitive Function and Decline in Late Life

Socioeconomic status in childhood and adulthood are key predictors of late life cognitive outcomes (Cagney & Lauderdale 2002; Fors, Lennartsson, & Lundberg 2009; Horvat et al. 2014). Though the mechanisms that underlie these life course links continue to be explored, it is thought that those who lack social and economic resources have lower access to cognitively stimulating work and activities, increased exposure to stress, poorer diet, reduced physical activity, and less social support, thus impacting long-term cognitive outcomes (Andel et al. 2007; Brown 2010; Bassuk et al. 1999; Cotman & Berchtold 2002). Further, aligned with the sensitive periods model, exposure to socioeconomic disadvantage in childhood has the potential to influence brain development and subsequent cognitive outcomes in adulthood (Hackman & Farah 2009; Noble et al. 2012; McEwen & Gianaros 2010).

In addition to the association of SES and late life cognitive function, growing evidence suggests that socioeconomic conditions influence age trajectories of cognitive decline, although this evidence is mixed. For example, while some longitudinal studies have found that those from disadvantaged socioeconomic backgrounds experience more rapid cognitive decline in late life (Everson-Rose et al. 2003; Koster et al. 2005), others have found little SES-based divergence in cognitive trajectories with age (Lyu & Burr 2016). These inconsistencies might be due in part to the lack of consideration for cohort differences in the relationship between SES and cognitive decline. Looking at cohort differences would improve current understandings of age trajectories of cognitive decline by considering how the unique contextual factors experienced across birth cohorts produce variations in cognitive trajectories.

Further, the timing of socioeconomic exposures across the life span could have significant implications for the onset and progression of cognitive decline. The majority of studies find that both early life and adult socioeconomic conditions are associated with adult cognitive outcomes, though the association of adult SES with cognitive function is of greater magnitude than early life SES (Luo & Waite 2005; Everson-Rose et al. 2003; Fors, Lennartsson, & Lundberg 2009). A longitudinal examination of these associations across cohorts will determine whether the associations of early life and adult SES with cognitive outcomes change across the life span. While the nature of these associations remain unknown within the cognition literature, examinations of the life course associations of early life and adult SES with physical health outcomes find evidence for the weakening importance of early life SES on health with age (Yang et al. 2017).

Building on prior research, I hypothesize that within cohorts, socioeconomically disadvantaged adults will have significantly lower mean cognitive function than those who are not disadvantaged. Further, aligned with research examining life course patterns of SES and health trajectories, I assume that the association of early life socioeconomic disadvantage with cognitive function will decrease over the life course, while the association of adult disadvantage with cognitive function will increase over the life course.

Inter-Cohort Variations in Socioeconomic Disparities in Cognitive Decline

Beyond examining variation in mean levels of cognitive function across cohorts, a longitudinal cohort design allows for examination of inter-cohort differences in intra-cohort heterogeneity in cognitive outcomes. In other words, do patterns of socioeconomic inequality in cognitive function differ across cohorts? Variations in social and economic environments experienced by different cohorts are likely to lead to cohort differences in how socioeconomic inequalities in cognitive function unfold across time.

First, over the past century, the U.S. has seen a rise in overall educational attainment, enabling more individuals from disadvantaged socioeconomic backgrounds to access secondary and post-secondary education. For example, in 2015, 88% of the U.S. population aged 25 and older had completed high school, compared to 75% in 1986, 50% in 1967, and 25% in 1940 (Ryan & Bauman 2016). Similar patterns are observed for college completion, with 33% of adults aged 25 and older completing college as of 2015, up from 15% in 1976 (Ryan & Bauman 2016). Given these educational increases, one would expect to see a weakening association of early life SES with cognitive outcomes across cohorts, as individuals are increasingly more likely to complete high school and college even if their parents did not. It remains unclear, however, how increasing educational attainment will affect educational gaps in cognitive outcomes. As more individuals earn high school or college diplomas, those who do not complete high school in more recent cohorts may become especially disadvantaged due to decreasing relative status in society, suggesting that educational gaps in cognitive outcomes might actually increase across cohorts.

In addition to education, income and wealth gaps in cognitive outcomes potentially differ across cohorts. Overall, Americans have enjoyed increasing economic prosperity over the past century. For example, the inflation-adjusted median household income in 2015 was $55,775, compared to $49,631 in 1985 (Proctor 2016). Assuming that income is an important contributor to adult cognitive outcomes, this income gain across time suggests that more recent cohorts will have better cognitive outcomes due to economic progress. However, it is important to note that these overall income gains did not occur in a linear fashion, but were heavily influenced by macro-level economic shocks that produced fluctuations in median income. For example, during the Great Depression, the unemployment rate is thought to have reached at least 23%, with implications for a substantial income loss among American families (Granados & Diez Roux 2009). More recently, the Great Recession was characterized by significant increases in unemployment and a 6.7% reduction in the median household income from 2007 to 2010, the most drastic decrease since World War II (Wolff 2016). Given these non-linear economic shifts across U.S. history, socioeconomic disparities in cognitive function might vary across cohorts in a non-linear fashion, with cohorts who experienced economic shocks during a formative developmental period or during an important stage of labor market participation at greater risk of cognitive decline.

Beyond trends in the median income, it is important to consider how growing income and wealth inequality has contributed to cohort differences in cognitive health disparities in the U.S. According to the U.S. Census, the inflation-adjusted income of the bottom quintile of American households increased 20% (from $9,929 to $12,457) from 1967 to 2015, while the income of the top quintile increased 50% (from $174,471 to $350,870) within the same time period (U.S. Census Bureau 2016). Given that income and wealth inequality are widening in the U.S., one would expect that socioeconomic inequalities in cognitive outcomes have also widened across cohorts, even if mean-level income gains are observed.

The Present Study

Building on current understanding of the social contributors to cognitive outcomes across the life span, the present study employs life course concepts to test for social conditions that shape cohort differences in cognitive function and decline. Using a national, longitudinal sample of older U.S. adults, I first test whether patterns of cognitive function and decline vary significantly across five birth cohorts. Next, I test the association of life course socioeconomic disadvantage with cognitive function and decline within cohorts. Finally, I determine whether associations of life course socioeconomic disadvantage with cognitive function and decline vary across birth cohorts. This work is designed to enhance our understandings of the complex social determinants of late life cognitive health and disease by highlighting larger demographic trends in cognitive outcomes that are reflective of socioeconomic change across the past century.

Data

The data come from the *Health and Retirement Study* (HRS), a nationally representative longitudinal sample of U.S. adults age 50 and older. Initial interviews of respondents and spouses took place from 1992-1993, with follow up interviews on alternating years until 2012. Additional cohorts were added to the original HRS sample in 1998, 2004, and 2010, bringing the total sample size to more than 26,000 adults. To maximize both sample size and the number of observations, the present study uses data collected from 1998-2012 (8 waves). More information about the HRS study design can be found at: http://hrsonline.isr.umich.edu/.

A significant strength of the HRS data is the longitudinal cohort design, which includes multiple defined birth cohorts from which to draw inferences on cohort effects. This study used longitudinal data available for five birth cohorts: the Study of Assets and Health Dynamics among the Oldest Old (AHEAD) cohort (born before 1924); Children of the Great Depression (CODA) cohort (born 1924-1930); HRS cohort (born 1931-1941); War Baby (WB) cohort (born 1942-1947); and the Baby Boomer (BB) cohort (born 1948-1969).

Including all respondents with complete data for the variables of interest, the present study has a final sample size of N=23,456 followed for a total of 76,879 observations. Among the 132,378 observations in the initial sample (spanning from 1998 to 2012), the majority of missing data (36%) was due to missing the cognitive tasks, either due to refusal to complete tasks or use of a proxy interviewer. Those who had a proxy interviewer due to cognitive impairment were imputed as having a cognitive score of zero; however, those who had a proxy interviewer for other reasons were omitted from the analysis. Among those with cognitive data, an additional 8% were missing a measure of parent education, and 11% were missing a measure of father unemployment.

Measures

<u>*Cognitive Function*</u>

A continuous, 35-point scale of cognitive function was constructed for each of the 7 waves included in the analysis (1998-2010), with higher values reflecting higher cognitive functioning (Weir et al 2013). Measures include immediate and delayed word recall to test memory (20 items), a serial sevens subtraction test of working memory (5 items), a backwards counting task to gauge speed of mental processing (one item with scores ranging from 0-2), an object naming test (2 items), and recall of the date, the current president, and vice president to gauge orientation (6 items). Values were imputed to replace missing values, refusals, and not applicable responses. Responses of "don't know" were recoded as incorrect. No imputations were calculated for non-participants at a given wave or respondents who were represented by a proxy interviewee due to severe physical disability. Respondents who were represented by a proxy interviewee due to severe cognitive impairment were imputed as receiving a cognitive function score of zero. More information about the cognitive function scale construction and imputation procedures can be found in documentation supplied by the RAND Corporation (Weir et al. 2013).

<u>*Socioeconomic Disadvantage*</u>

Early life disadvantage was captured using three retrospective measures of socioeconomic disadvantage before the age of 16: low parent educational attainment, perceived low childhood SES, and father unemployment. For low parent educational attainment, respondents reported maximum education levels for both parents. Those who reported less than a high school education for both parents (or for one parent in a single parent household) were coded as having parents with low educational attainment. Second, respondents were asked whether their family was "pretty well off financially, about average, or poor" from their birth to age 16. Those who responded "poor" were coded as disadvantaged. Finally, respondents were asked whether their father had no job for a time of several months or more before the respondent was age 16. This item was dichotomized, with those reporting father unemployment coded as disadvantaged.

Adult disadvantage was captured using three indicators of socioeconomic disadvantage in adulthood, including educational attainment, household income, and household assets. Educational attainment was recoded as a binary indicator in which respondents with less than a high school education were coded as disadvantaged. Household income and assets were used across all eight waves of data from 1998 to 2012. To measure disadvantage, both income and assets were dichotomized in each wave, with the bottom quartile of income and assets coded as disadvantaged.

<u>Age</u>

Age was coded as a continuous measure, and was mean-centered with the youngest age in the sample (age 50) coded as zero. This produced a continuous age-centered variable with a range of 0-59 (representing ages 50-109). In addition, age was multiplied on itself to create a quadratic function of age, age^2.

<u>Covariates</u>

I included several controls that potentially contribute to socioeconomic disparities in cognitive outcomes within and across cohorts. First, I adjusted for a retrospective measure of childhood self-rated health (SRH) to account for possible selection into educational, economic, and cognitive trajectories. I also adjusted for time-varying indicators of body mass index (BMI) and cigarette smoking in adulthood. I also included a binary indicator of marital status (1=married), and a binary indictor of retirement (1=fully retired). All models adjust for demographic characteristics such as sex and race/ethnicity (1=white, 2=black, 3=Hispanic, 4=other), and death and nonresponse as reasons for attrition from the survey.

Methods

I employed Hierarchical Age-Period-Cohort growth models (HAPC-GM) to estimate both intra-cohort and inter-cohort age trajectories of cognitive function in adulthood (Yang & Land 2013). Consistent with typical growth curve models, the data is composed of two levels, with repeated measures of individuals across time at level 1, and individuals at level 2 (Raudenbush & Bryk 2002). The level 1 model is specified below:

$$Y_{ti} = \beta_{0i} + \beta_{1i} Age_{ti} + \beta_{2i} Age_{ti}^2 + e_{ti}$$

where Y_{ti} is cognitive function for person *i* at time *t,* β_{0i} is the intercept, β_{1i} is linear growth rate*,* β_{2i} is the quadratic growth rate, and e_{ti} is the within-person error term.

The level 2 models estimate age trajectories of cognitive outcomes as a function of Cohort, Cohort^2, early life and adult socioeconomic indicators (SES), and the interaction of SES and Cohort.[6]

For the intercept:

$$\beta_{0i} = \gamma_{00} + \gamma_{01} Cohort_i + \gamma_{02} SES_{ti} + \gamma_{03} SESxCohort_i + u_{0i}$$

For the linear growth rate:

$$\beta_{1i} = \gamma_{10} + \gamma_{11} Cohort_i + \gamma_{12} SES_{ti} + u_{1i}$$

[6] For SES items, four are modeled as time-invariant (parent education, respondent education, perceived childhood SES, father unemployment) and two are modeled as time-varying across the study period (income and assets).

where γ_{01} - γ_{04} are coefficients for Cohort, Cohort squared, SES variables, and SES x Cohort variables, respectively.

Time-varying covariates are entered at level-1 (income, assets, married, BMI, smoker, retired), and time-invariant covariates at level-2 (childhood SES measures, gender, race, death, nonresponse).

Several weighting approaches were used to test for sensitivity of results to the sampling design and study attrition. In addition to unweighted analyses, I repeated all analyses using base year weights to correct for differential probability of selection into the study and initial study response rates (Heeringa & Connor 1995). Because using base year weights does not account for attrition across the study, I also repeated all analyses using end year weights. These are the two primary approaches suggested by HRS investigators regarding the incorporation of weights in longitudinal analyses using HRS (Ofstedal et al. 2011). While neither approach can account for all possible sources of bias, comparison of results from the use different weighting approaches provides insight into the ways in which both sampling and attrition influence estimates. All reported results use base year weights because this weighting approach is most appropriate for prospective analyses in which the aims are to model future trajectories of a population (Ofstedal et al. 2011).

Results

Table 4-1 shows the total number of observations by age and cohort, demonstrating sufficient representation of adults aged 50 and over, as well as substantial age overlap across cohorts.

Descriptive results

Table 4-2 shows descriptive statistics for the total number of observations in the study, both for the full sample and within each cohort. Among all observations in the full sample, respondents have a mean score of 21.0 for cognitive function (range 0-35), with cognitive scores appearing to increase across successive cohorts (from 17.0 in AHEAD to 23.3 in Baby Boomers). Low parent education appears to be most prevalent in older cohorts, with 62.2% for all observations, 98.2% for AHEAD, and 32.0% for Baby Boomers. Conversely, perceptions of low childhood SES appear to be higher for more recent cohorts. Finally, father unemployment peaks for the CODA cohort at 27.3%, then steadily declines in more recent cohorts. Respondent educational attainment in adulthood also appears to increase across (32.5% with less than a high school education in AHEAD, compared to 10.7% in the Boomers). More recent cohorts are also less likely to in the bottom quartile of household income or assets.

<u>*Growth curve results*</u>

Recall that the goals of the growth curve analyses are to: 1) test for inter-cohort variation in cognitive function and decline, 2) test for intra-cohort socioeconomic inequalities in cognitive health, and 3) test for inter-cohort variation in intra-cohort socioeconomic inequalities in cognitive health. Presentation of results is organized according to these three goals.

Inter-cohort change. Table 4-3 shows HAPC-GM results for the full sample.[7] In Model 1, linear and quadratic terms for age describe a curvilinear relationship in which the association of age with cognitive function is initially positive (coef. for age=0.204, p<0.001) but declines with age (coef. for age^2=-0.013, p<0.001). Model 2 incorporates estimates for mean cohort differences and cohort differences in age trajectories of cognition, and shows no significant difference in cognition by cohort (coef.=-0.074, p=0.482). However, the negative coefficient for the linear growth rate of cohort shows that more recent cohorts have faster rates of cognitive

[7] Table 3 shows weighted HAPC-GM estimates using weights at baseline. Appendix Table 1 shows unweighted estimates and Appendix Table 2 shows weighted estimates using weights at study exit.

decline relative to prior cohorts (coef.=-0.052, p<0.001). These differing rates of cognitive decline are illustrated in Figure 4-1.

Intra-cohort inequality. Model 3 of Table 4-3 includes estimates for the intercept and age interactions for three indicators of early life socioeconomic disadvantage. Having parents with less than a high school education and a father who was unemployed during the respondent's childhood are associated with lower cognitive function in late adulthood (Parent less than HS=-1.485, p<0.001; Father unemployment=-0.394, p=0.007). However, while nonsignificant estimates for the linear growth rate indicate that parent education and father unemployment are not associated with age trajectories of cognitive decline, respondent perceptions of low childhood SES are associated with widening cognitive disparities (coef.=0.026, p=0.017). Inclusion of indicators of adult socioeconomic disadvantage in Model 4 shows that respondents with an educational attainment of less than high school score 3.2 points lower on the cognitive task compared to those with more education (p<0.001), making educational attainment the strongest socioeconomic predictor of cognitive function among the variables included in the analysis. Low income and assets are also associated with worse cognitive function (Low income=-1.413, p<0.001, Low assets=-0.745, p<0.001). Interestingly, when looking at the interaction of education and assets with age, educational disparities in cognitive function narrow with age (coef.=-0.024, p=0.009), while income disparities in cognitive function widen with age (coef.=0.037, p<0.001). Further, inclusion of adult SES items in Model 4 partially attenuates associations of low parent educational attainment and father unemployment with cognitive function, though both estimates remain statistically significant.

Inter-cohort difference in intra-cohort inequality. Model 5 includes interactions of early life and adult SES items with cohort. Results indicate a significant interaction of parent educational attainment, adult household income, and adult household assets with cohort. To illustrate cohort differences in the links between life source socioeconomic disadvantage and cognitive function, I ran growth curve models stratified by cohort and plotted model coefficients in Figure 4-2. Estimates from stratified models enable observation of potentially non-linear cohort differences in socioeconomic disparities in cognition. Results from Figure 2 show cohort differences in associations of both early life and adult socioeconomic disadvantage with cognitive function.[8] According to Figure 4-2a, low parent education is not associated with cognitive outcomes among respondents from the CODA cohort, but low parent education appears to be significantly associated with cognitive function among the HRS, WB, and BB cohorts in a graded fashion (that is, the association between low parent education and cognitive function is strongest among the BB cohort and weakest among the HRS cohort). Figure 2b shows cohort differences in the association of low respondent education with cognitive outcomes in adulthood. Respondent education appears to be an important determinant of cognitive outcomes within every cohort except for the CODA cohort. The non-linear cohort differences in the links between education and cognition explain why significant educational disparities were not observed when cohort was modeled as a continuous predictor in Table 4-3. Figure 4-2c shows significant cohort differences in the association of low income with cognitive outcomes, with narrowing cohort differences in the links between income and cognition across AHEAD, CODA, and HRS, followed by diverging impacts of income on cognition across HRS, WB, and BB cohorts. In other words, income inequalities in cognitive outcomes appear greatest in the AHEAD and BB cohorts, and narrowest in the HRS cohort. A similar cohort pattern is observed for low household assets in Figure 2d.

[8] See Appendix Table 3 for all estimates from stratified models.

Finally, Model 6 adjusts for self-rated childhood health, BMI, cigarette smoking, marital status, and retirement status. Better childhood self-rated health and higher adult BMI are associated with higher cognitive function in adulthood. Interestingly, being married is associated with lower cognitive function, and being retired is associated with higher cognitive function, which warrants further examination. However, inclusion of these controls does not significantly alter the age or cohort trajectories of cognitive function, or the associations of socioeconomic disadvantage with cognitive outcomes.

Discussion

Using a national, longitudinal study of U.S. adults, the present study investigates cohort differences in the links between socioeconomic conditions and adult cognitive outcomes. Overall, findings identify that cohort membership is important to consider when examining cognitive health disparities in the U.S. While no significant cohort differences in mean cognitive function were found after accounting for sample design, estimates indicate that more recent cohorts are on a trajectory toward significantly faster rates of cognitive decline compared to prior cohorts. These results conflict with prior research that identifies improvements in cognitive outcomes among more recent cohorts (Langa et al. 2017; Berg & Steen 1998; Christensen et al. 2013; Rowe & Kahn 1987). However, these results are consistent with the Hulur et al. finding using AHEAD, in which recent cohort improvements in cognitive outcomes disappeared after accounting for elements of the survey design.

The present work also identifies overall links between life course socioeconomic disadvantage and cognitive outcomes. The experience of socioeconomic disadvantage in both childhood and adulthood is associated with significantly lower cognitive function in late adulthood. Not surprisingly, parent and respondent education appear to be especially salient predictors of late life cognitive function, while adult income and assets play a smaller yet significant role in predicting cognitive outcomes. Components of socioeconomic disadvantage also appear to differentially influence age trajectories of cognitive decline: the association of respondent low educational attainment with cognitive function narrows with age, while the association of adult household income with cognitive function widens with age. Because educational attainment is typically completed by young adulthood, the weakening of educational effects across time could be due to the greater temporal distance from educational experiences with age. Meanwhile, as educational attainment becomes less important, household income becomes more important with age, possibly because household income is a more proximal indicator of SES that has immediate influences on cognitive outcomes.

It is also possible that mortality selection could lead to a narrowing of the association between educational attainment and cognitive outcomes with age; in other words, those with lower educational attainment and lower cognitive function are more likely to die younger, thus producing estimates that show narrowing socioeconomic inequalities in cognitive function with age. However, as shown in Appendix Table 2, educational disparities in cognitive function continue to narrow after inclusion of end weights that account for sample attrition. Further, other socioeconomic indicators are associated with diverging age trajectories in cognitive outcomes. Therefore, mortality selection is an unlikely explanation for observed socioeconomic patterns.

In addition to overall associations of life course socioeconomic disadvantage with cognitive outcomes, this research identifies significant inter-cohort heterogeneity in the links between socioeconomic disadvantage and cognitive function. With the exception of parent education, which shows linear increases in cognitive disparities between those with low-educated and higher-educated parents, these associations appear to be non-linear. For example, the links between low respondent education and cognitive function are apparent in the AHEAD, HRS, WB, and BB cohorts, but are not significant for the CODA cohort. I also found non-linear cohort differences in the association of income and wealth with cognitive function, with a stronger influence of income and wealth inequalities among the oldest (AHEAD) cohort, weaker associations among the CODA and HRS cohorts, and strengthening associations among the more recent WB and BB cohorts. These non-linear trends could be due to cohort differences in the timing in which they experienced the Great Depression and Great Recession. The AHEAD cohort entered the labor force during the Great Depression, which had a negative impact on early earnings that potentially carried throughout the life span. Meanwhile, the War Baby and Baby Boomer cohorts were in the labor force during the Great Recession, and those at the bottom of the income and wealth distribution likely felt the economic shocks of the Recession more than those at the top of the distribution.

CODA appears to be a unique cohort for socioeconomic inequalities in cognitive function, as the association socioeconomic disadvantage across education, income, and assets with cognitive outcomes appears to be the weakest for the CODA cohort. While the CODA cohort were infants and children during the far-reaching experiences of socioeconomic disadvantage of the Great Depression, they entered the labor force during the economic boom resulting from World War II in the 1940s. Men who enlisted in the War also benefitted from the 1944 G.I. Bill that provided tuition payments, low-cost mortgages, low-interest business loans, and unemployment compensation (Bennett 1996). These provisions offered greater opportunities for veterans to gain economic status, with or without education. Finally, most of the CODA cohort exited the labor force prior to the Great Recession in 2008 and were thus shielded from many of the financial blows experienced by younger Americans.

As indicated by Appendix Tables 1 and 2, the estimates for cohort differences in cognitive function and socioeconomic inequalities in cognitive function across cohorts are highly sensitive to adjustments for sample design. In fact, in the unweighted analyses shown in Appendix Table 1, it appears that more recent cohorts have significantly better cognitive function relative to prior cohorts, which is consistent with previous literature. However, these cohort improvements in mean cognitive function disappear after inclusion of base weights (that adjust for sample selection and initial response rates) or end weights (that adjust for survey attrition). Therefore, it is possible that observed cohort improvements in cognitive function are an artifact of survey design. These findings are supported by several previous studies that used the AHEAD sample and found that observed cohort improvements in cognitive function disappeared after accounting for sample design (Rodgers, Ofstedal, & Herzog 2003; Hulur et al. 2013). This research extends on this prior work by identifying the importance of adjusting for sample design among the entire HRS sample, not just AHEAD.

The finding that more recent cohorts have worse cognitive outcomes warrants further study. The War Babies and Baby Boomers may be more prone to cognitive decline due to population shifts across social, economic, and health-related domains. For example, as previously addressed, more recent cohorts were in the workforce during the Great Recession, and are also more likely to be impacted by goring socioeconomic inequalities in the U.S. More recent cohorts also enjoy better physical health due to increased medication use to control hypertension, high cholesterol, and diabetes. However, a number of medications to treat the symptoms of physical aging have been shown to cause “drug-induced cognitive impairment” (Bowen & Larson 1993; Gray, Lai, & Larson 1999). Future analysis should investigate whether cohort changes in medication use contribute to cohort differences in cognitive decline.

There are several limitations to this work that warrant further research. First, I rely on cognitive tasks that primarily measure episodic and working memory, which is only a portion of global cognitive function. However, while these measures represent a component of cognitive abilities, prior work has identified working memory as a significant proxy for more global cognition (Conway, Kane, & Engle 2003). Second, while the analyses incorporate weights to account for survey design, other elements of the study procedure could bias results. Specifically, the AHEAD and CODA cohorts entered the study at older ages, meaning that mortality selection prior to the start of the study could more strongly affect estimates for these groups. Third, repeated testing might be an issue. Given that the cognitive tasks are repeatedly administered to respondents, older cohorts have taken the cognitive tasks more times than younger cohorts, potentially leading to inflated cognitive scores for older cohorts. For example, if we were to compare the score of a 60 year old taking the cognitive tests for the first time to a 60 year old who had taken the cognitive tests every other year since the age of 50, we would expect that the latter participant would do better due to prior exposure to the tasks (Rodgers, Ofstedal, & Herzog 2003).

Nevertheless, this research has many important strengths, including a longitudinal panel design with multiple waves of socioeconomic and cognitive data, advanced modeling of cohort effects, and consideration of how life course socioeconomic inequalities in cognitive function unfold differently across birth cohorts. These findings highlight the need to consider the unique social and economic contexts experienced by different birth cohorts that contribute to variation in late life cognitive trajectories. These findings also challenge more optimistic prior findings of cohort improvements in late life cognitive decline, thus calling for further research to identify interventions to reverse the worsening cognitive health of older adults in the U.S.

This research opens the door for future research endeavors. In addition to examining the changing socioeconomic gaps in cognitive outcomes across cohorts, future research should take an intersectional approach to consider how SES, sex, and race combine to differentially shape cognitive outcomes across cohorts. Further, inclusion of county, state, or regional socioeconomic variables in future analyses would provide further evidence for the importance of socioeconomic contexts in shaping cognitive function and decline. Nonetheless, this research answers fundamental questions about inter-cohort and intra-cohort patterns of cognitive function and decline, and has important implications for improving public health and wellbeing.

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Table 4-1. *HRS Age by Cohort Crosstabulation*

Age	AHEAD	CODA	HRS	WB	BB	Total
50	0	0	0	122	512	**634**
51	0	0	0	339	957	**1,296**
52	0	0	0	258	1,048	**1,306**
53	0	0	0	263	967	**1,230**
54	0	0	0	239	923	**1,162**
55	0	0	0	266	847	**1,113**
56	0	0	12	139	587	**738**
57	0	0	24	23	256	**303**
58	0	0	17	20	174	**211**
59	0	0	20	20	168	**208**
60	0	0	31	25	129	**185**
61	0	0	29	9	138	**176**
62	0	0	35	16	104	**155**
63	0	0	30	37	24	**91**
64	0	0	328	35	12	**375**
65	0	0	2,668	1,100	1	**3,769**
66	0	0	2,896	809	0	**3,705**
67	0	199	2,846	683	0	**3,728**
68	0	428	2,590	619	0	**3,637**
69	0	636	2,699	405	0	**3,740**
70	0	765	2,627	238	0	**3,630**
71	0	925	2,653	5	0	**3,583**
72	0	1,122	2,322	0	0	**3,444**
73	0	1,194	2,011	0	0	**3,205**
74	233	1,254	1,723	0	0	**3,210**
75	395	1,146	1,460	0	0	**3,001**
76	558	1,076	1,207	0	0	**2,841**
77	752	1,057	913	0	0	**2,722**
78	816	1,071	697	0	0	**2,584**
79	960	842	611	0	0	**2,413**
80	998	944	339	0	0	**2,281**
81	1,084	841	168	0	0	**2,093**
82	1,087	841	2	0	0	**1,930**
83	1,089	658	0	0	0	**1,747**
84	1,150	497	0	0	0	**1,647**
85	1,109	362	0	0	0	**1,471**
86	1,002	297	0	0	0	**1,299**
87	979	161	0	0	0	**1,140**
88	967	74	0	0	0	**1,041**
89	813	0	0	0	0	**813**
90	737	0	0	0	0	**737**
91	581	0	0	0	0	**581**
92	482	0	0	0	0	**482**
93	343	0	0	0	0	**343**

94	255	0	0	0	0	**255**
95	197	0	0	0	0	**197**
96	138	0	0	0	0	**138**
97	102	0	0	0	0	**102**
98	66	0	0	0	0	**66**
99	49	0	0	0	0	**49**
100	31	0	0	0	0	**31**
101	19	0	0	0	0	**19**
102	13	0	0	0	0	**13**
103	3	0	0	0	0	**3**
104	3	0	0	0	0	**3**
106	2	0	0	0	0	**2**
109	1	0	0	0	0	**1**
Total	**17,014**	**16,390**	**30,958**	**5,670**	**6,847**	**76,879**

Table 4-2. *HRS Descriptive Statistics across Cohorts, % / Mean(SD)*

	Full Sample	**AHEAD**	**CODA**	**HRS**	**WB**	**BB**
N	76,879	17,014	16,390	30,958	5,670	6,847
Cognitive function	21.0 (6.7)	17.0 (8.0)	20.9 (6.3)	22.3 (5.7)	23.6 (5.2)	23.3 (4.6)
Low parent education	62.2	98.2	62.2	53.3	39.4	32.0
Low childhood SES	7.7	7.7	7.5	6.8	9.9	10.7
Father unemployment	23.0	26.0	27.3	20.7	19.7	18.9
Low respondent education	22.3	32.5	22.2	20.8	13.5	12.4
Low household income	25.2	39.6	22.5	22.2	13.9	19.6
Low household assets	21.7	28.2	16.6	19.1	17.2	33.5
Age	72.7 (9.8)	84.2 (5.5)	76.3 (4.9)	70.4 (4.1)	62.6 (6.5)	53.9 (2.9)
Female	57.3	63.5	55.3	56.2	56.9	51.5
Race						
White	84.4	88.7	90.5	83.6	83.7	63.4
Black	11.8	9.8	6.8	12.9	11.6	24.0
Other	3.8	1.6	2.7	3.5	4.6	12.6
Died	25.1	63.1	27.4	12.0	4.0	1.8
Nonresponse	12.8	11.7	12.3	14.0	16.9	8.2
Childhood SRH	4.4 (0.9)	4.2 (0.9)	4.4 (0.9)	4.4 (0.8)	4.5 (0.8)	4.3 (0.9)
Current smoker	10.7	4.3	7.9	11.8	17.1	23.5
BMI	27.1 (5.4)	24.9 (4.6)	26.5 (4.8)	27.9 (5.4)	28.7 (5.9)	29.1 (6.3)
Married	60.5	37.9	64.2	66.4	75.9	68.0
Retired	64	75.6	76.6	67.8	43.2	4.9

Note: Sample sizes indicate the total number of observations (not the number of respondents).

Table 4-3. *Cohort Differences in the Association of Life Course Socioeconomic Disadvantage with Cognitive Decline (N=23,456)*

Fixed Effects Parameters						
For the Intercept						
Intercept	24.145***	24.825***	25.738***	27.245***	25.355***	23.218***
	(0.084)	(0.525)	(0.531)	(0.495)	(0.538)	(0.593)
Cohort		-0.074	-0.192+	-0.408***	-0.056	-0.041
		(0.106)	(0.106)	(0.099)	(0.108)	(0.107)
Low parent education			-1.485***	-0.743***	0.221	0.217
			(0.134)	-0.124	(0.479)	(0.478)
Low childhood SES			0.012	0.034	-0.395	-0.413
			(0.186)	(0.179)	(0.767)	(0.767)
Father unemployment			-0.394**	-0.307*	0.065	0.039
			(0.147)	(0.137)	(0.511)	(0.509)
Low respondent education				-3.241***	-2.739***	-2.642***
				(0.208)	(0.621)	(0.621)
Low household income				-1.413***	-0.281	-0.337
				(0.160)	(0.532)	(0.534)
Low household assets				-0.745***	1.074+	0.995+
				(0.132)	(0.555)	(0.554)
Low parent education X Cohort					-0.200*	-0.197*
					(0.100)	(0.100)
Low childhood SES X Cohort					0.078	0.083
					(0.155)	(0.155)
Father unemployment X Cohort					-0.083	-0.066
					(0.104)	(0.103)
Low respondent education X Cohort					-0.152	-0.156
					(0.130)	(0.130)
Low household income X Cohort					-0.243*	-0.231*
					(0.106)	(0.106)
Low household assets X Cohort					-0.339**	-0.316**
					(0.110)	(0.110)

For the Linear Growth Rate						
Intercept	0.204***	0.369***	0.408***	0.223***	0.376***	0.379***
	(0.009)	(0.035)	(0.035)	(0.033)	(0.036)	(0.036)
Cohort		-0.052***	-0.060***	-0.034***	-0.050***	-0.052***
		(0.005)	(0.006)	(0.005)	(0.006)	(0.006)
Low parent education			-0.006	-0.001	-0.014	-0.014
			(0.008)	(0.007)	(0.011)	(0.011)
Low childhood SES			0.026*	0.007	0.020	0.020
			(0.011)	(0.010)	(0.018)	(0.018)
Father unemployment			0.013+	0.013*	0.008	0.009
			(0.007)	(0.007)	(0.012)	(0.012)
Low respondent education				-0.024**	-0.020	-0.020
				(0.009)	(0.015)	(0.015)
Low household income				0.037***	0.010	0.010
				(0.006)	(0.012)	(0.012)
Low household assets				0.000	-0.057***	-0.056***
				(0.006)	(0.013)	(0.013)
For the Quadratic Growth Rate						
Intercept	-0.013***	-0.015***	-0.015***	-0.011***	-0.014***	-0.014***
	(0.000)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)
Control Variables						
Female	0.895***	0.794***	0.844***	0.979***	0.897***	0.911***
	(0.074)	(0.073)	(0.073)	(0.066)	(0.069)	(0.070)
Race (ref. White)						
Black	-3.837***	-3.653***	-3.338***	-2.659***	-2.568***	-2.610***
	(0.124)	(0.123)	(0.124)	(0.112)	(0.117)	(0.117)
Other	-2.955***	-2.800***	-2.374***	-1.645***	-1.548***	-1.503***
	(0.181)	(0.181)	(0.177)	(0.159)	(0.167)	(0.167)
Died	-1.129***	-2.249***	-2.153***	-1.500***	-1.738***	-1.667***
	(0.113)	(0.124)	(0.123)	(0.108)	(0.115)	(0.115)
Nonresponse	-0.426***	-0.495***	-0.471***	-0.513***	-0.453***	-0.459***
	(0.109)	(0.108)	(0.107)	(0.097)	(0.102)	(0.102)

Childhood SRH						0.353***
						(0.040)
BMI						0.021***
						(0.006)
Current smoker						-0.104
						(0.087)
Married						-0.130*
						(0.065)
Retired						0.137*
						(0.054)
Random Effects (Variance Components)						
Level 1: Within-person	1.262***	1.259***	1.260***	1.169***	1.262***	1.262***
Level 2: In intercept	-1.540***	-1.538***	-1.548***	-1.772***	-1.598***	-1.606***
Level 2: In growth rate	-0.459***	-0.497***	-0.496***	-0.477***	-0.534***	-0.526***
Goodness of Fit (BIC)	496234	495474	460916	457660	457693	447956

Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

__Figure 4-1__. Cohort Differences in Age Trajectories of Cognitive Decline (N=23,456)

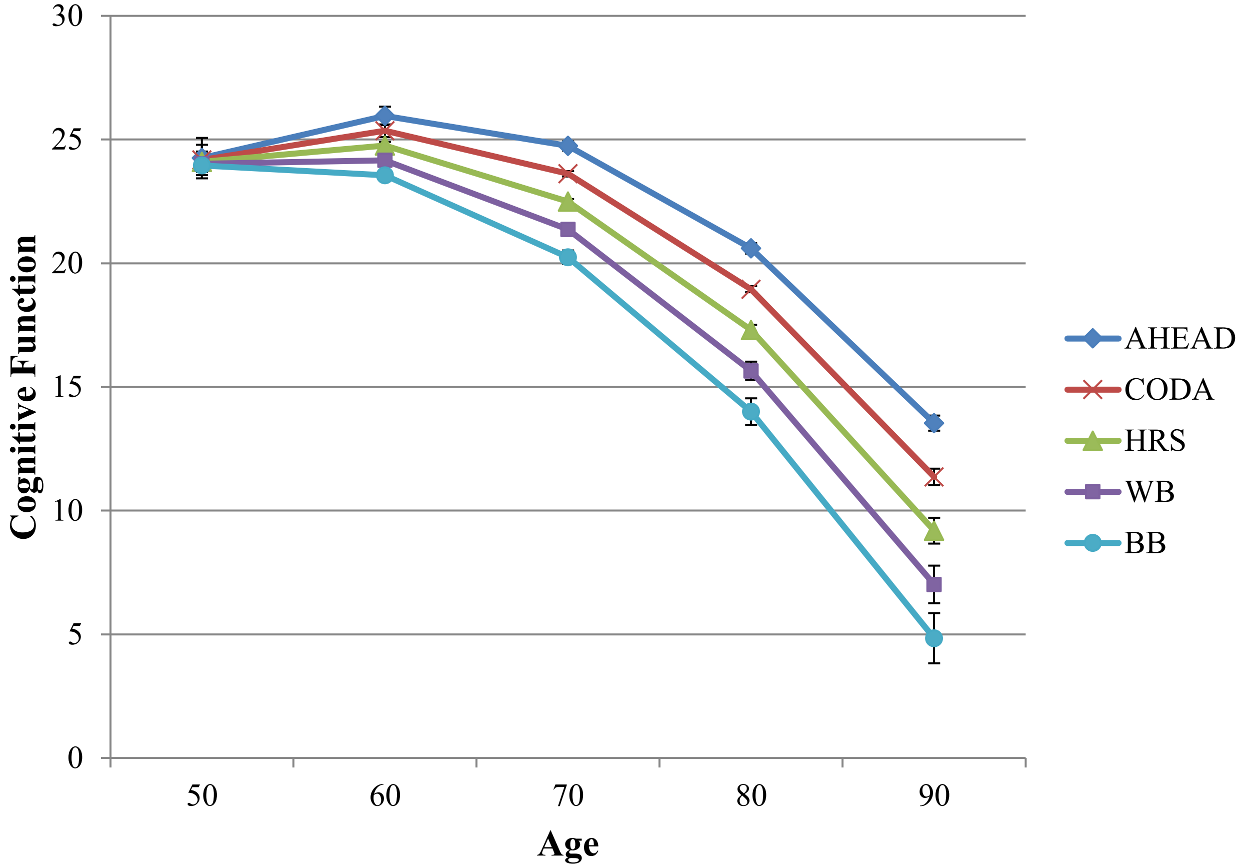
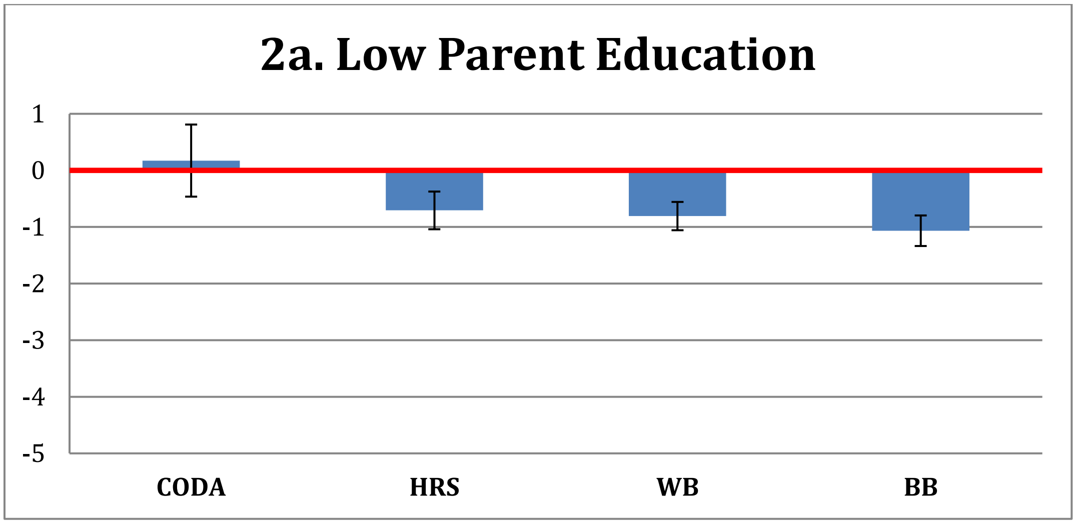
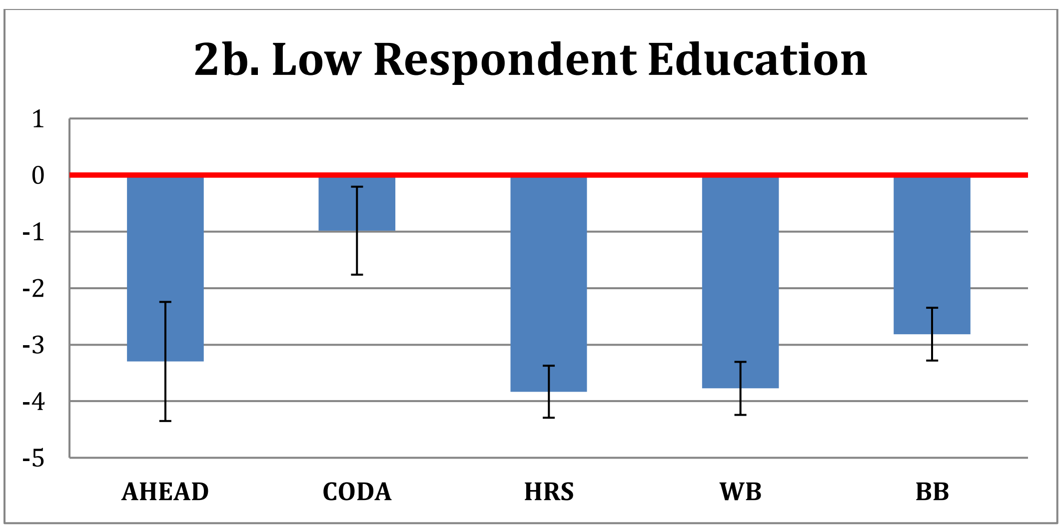
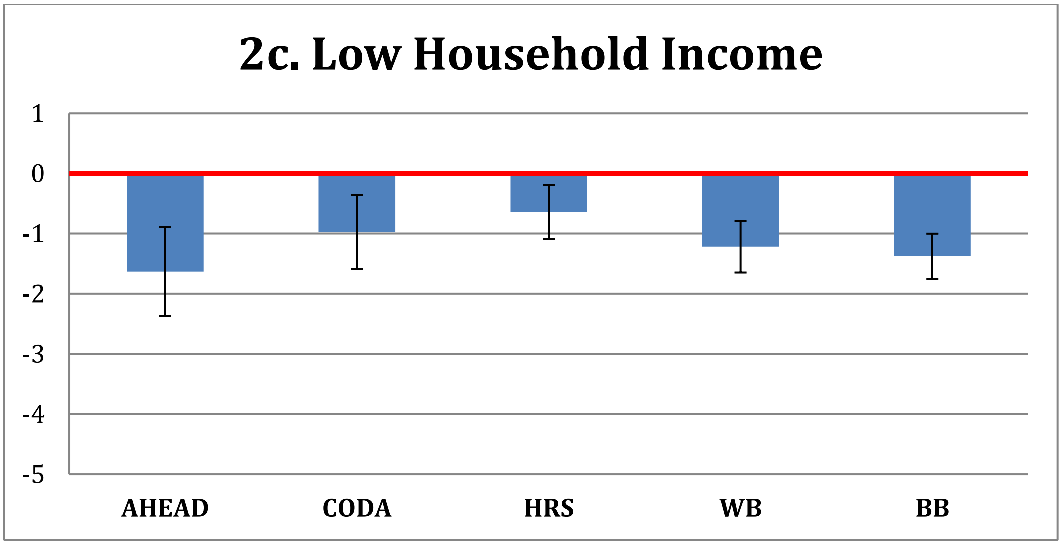


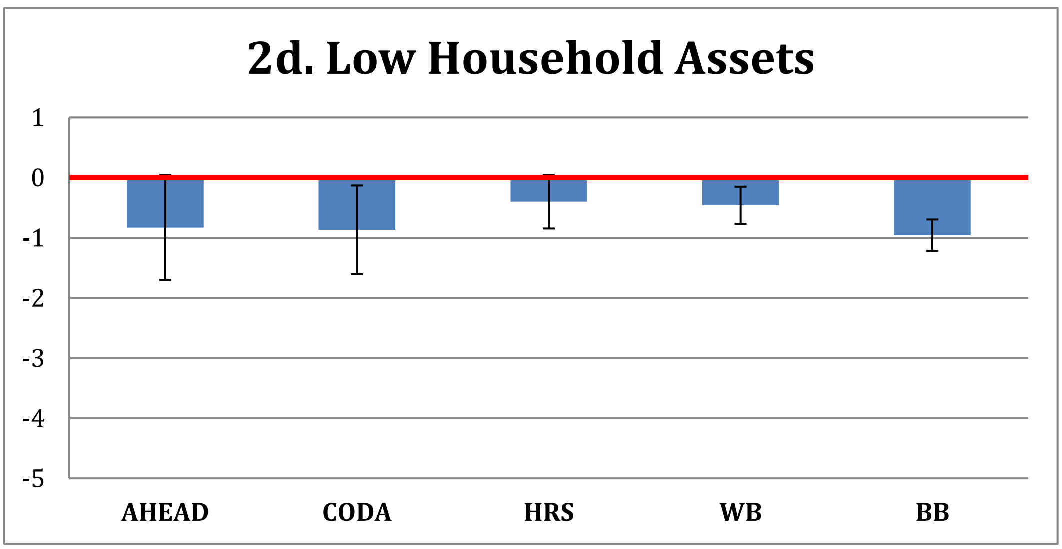
Figure 4-2*. Cohort Differences in the Association between Socioeconomic Disadvantage and Cognitive Function (N=23, 456))*



Note: Estimates for low parent education were omitted from the figure due to insufficient variation to measure cognitive disparities (98% of the AHEAD population reported low parent education).




2c. Low Household Income
1
0
-1
-2
-3
-4
-5
AHEAD
CODA
HRS
WB
BB


2d. Low Household Assets
1
0
-1
-2
-3
-4
-5
AHEAD
CODA
HRS
WB
BB

CHAPTER FIVE: CONCLUSIONS AND FUTURE DIRECTIONS

Drawing from life course perspective to chronic disease epidemiology, my dissertation uses a multilevel and longitudinal approach to identify the links between socioeconomic disadvantage and cognitive function across the life span. In addition to investigating overall patterns in socioeconomic status and cognitive outcomes across young, mid, and late adulthood, each chapter examines a potential source of variation in these associations. Chapter two tests whether school and neighborhood socioeconomic resources modify the link between adolescent household disadvantage and young adult cognitive outcomes. Chapter three examines whether conscientiousness modifies the link between early life socioeconomic disadvantage and adult cognitive function. Finally, chapter four tests whether the links between life course socioeconomic disadvantage and late life cognitive outcomes vary across birth cohorts. While each chapter focuses on a different source of variation (i.e., contextual, personality, historical), all of these examinations aim to convey the complexity and nuances of the relationship between socioeconomic conditions and cognitive function across the life course. In other words, among those from disadvantaged backgrounds, who is most at risk cognitive impairment and decline? And *why* are some at greater risk than others in different stages of the life course?

I found that surrounding socioeconomic environments, personality traits, and historical contexts do alter the links between socioeconomic disadvantage and cognitive outcomes. However, these patterns did not always emerge as expected. For example, rather than protect against the negative impacts of adolescent disadvantage, attending a more affluent school or residing in a more affluent neighborhood had no lasting cognitive benefit among adolescents from disadvantaged households. Instead, adolescents from higher SES households reaped the benefit of these affluent contexts. Further, birth cohorts did show differences in cognitive outcomes. However, counter to prior evidence of cognitive gains across cohorts (Langa et al. 2017; Steen, Berg, & Steen 1998; Christensen et al. 2013; Rowe & Kahn 1987), my findings indicate no improvements in baseline cognitive function across cohorts, and more rapid age trajectories of cognitive decline among more recent cohorts. These findings challenge the more optimistic findings about the sweeping benefits of economic advances on cognitive health. As the results to my research suggest, we need to rethink the ways in which resources are allocated across time and place to ensure that cognitive health inequalities are reduced. We also need to identify explanations for these troubling findings in order to reverse them.

My findings also suggest that analyses of the socioeconomic contributors to cognitive outcomes are incomplete without consideration of macro- and micro-level processes. While accounting for all variation in the associations between socioeconomic conditions and cognitive outcomes may not be possible, major contextual- and individual-level contributors to cognitive outcomes are accessible and increasingly available in population studies. Inclusion of these factors in conceptual models and analyses improves our understanding of the social contributors to cognitive health inequalities.

As research examining the social determinants of cognitive health inequalities continues to grow, there are several avenues of future research to consider. First, neurobiological indicators of structural and functional components of the brain are becoming more accessible for inclusion in social science research (Farah et al. 2006; Hackman & Farah 2009). Incorporation of these measures would aid in identifying the psychological factors that underpin the effects of disadvantage on cognitive outcomes. Second, future research could also benefit from genetic data in order to account for the partial heritability of cognitive functioning, or to explore the role of gene-environment interactions in producing cognitive outcomes (Sweet et al. 2012). Finally, while this work focuses exclusively on the socioeconomic contributors to cognitive outcomes, intersectional approaches that consider how race, SES, and gender interactively shape cognitive trajectories would strengthen our understanding of how gendered and racialized societies produce cognitive inequalities.

This research has important implications for policies and interventions aimed at multiple levels to prevent the emergence of cognitive inequalities. Because early life socioeconomic conditions appear to have important direct and indirect effects on adult cognitive outcomes, interventions to mitigate household socioeconomic inequalities would help to prevent cognitive impairment and decline. Reductions in early life household inequalities would not only influence individual the development of behaviors and personality traits related to physical and cognitive health, but would also contribute to trajectories of socioeconomic attainment that improve cognitive maintenance and slow cognitive decline in late adulthood. In addition, resources in neighborhood and school contexts are important contributors to long-term cognitive outcomes (Rutter 1985; Klebanov et al. 1998; Brooks-Gunn et al. 1993). Interventions should focus on ensuring that all children and adolescents can access and benefit from resources outside of the household, regardless of socioeconomic status. The development of personality traits in early life could also be a point of intervention. Parenting programs that target low SES families could provide parents with the tools to promote conscientious behaviors among children and adolescents, which could in turn improve cognitive trajectories into adulthood (Magnuson & Duncan 2002). Finally, interventions on more recent cohorts across social, economic, and behavioral domains could reverse trends of worsening cognitive health among older adults.

These interventions all have a focus on prevention by targeting the social, economic, and behavioral contributors to cognitive outcomes before the onset of cognitive decline. This approach builds on a life course perspective that emphasizes the multilevel and longitudinal dynamics that shape cognitive trajectories across developmental time. Intervening on early life socioeconomic exposures would set in motion both direct and indirect influences on cognitive trajectories. Not only is early life a time of simultaneous cognitive development and sensitivity to the environment, but early life socioeconomic conditions also set individuals on paths toward future status attainment, health, and wellbeing. Therefore, future research must consider adult cognitive aging as a process that begins long before the onset of cognitive decline. A focus on prevention will be most effective for improving cognitive health among future cohorts.

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APPENDIX 2-1. ASSOCIATION OF HOUSEHOLD INCOME WITH MEMORY FUNCTION AMONG THOSE FROM AFFLUENT SCHOOLS (N=1,324)

	Baseline	Selection Processes	Adolescent Resources	Academic Performance	Adolescent Mental Health	Status Attainment	Adult Mental Health	Adult Health Behaviors	Full Model
FIXED EFFECTS									
Intercept	18.11***	6.91**	4.38+	7.61***	7.24**	7.07**	8.06***	8.04***	8.74***
	(2.87)	(2.25)	(2.34)	(2.21)	(2.75)	(2.63)	(2.26)	(1.86)	(2.31)
Low adolescent household income	-1.54***	-1.31**	-1.17**	-1.14**	-1.26**	-0.93*	-1.29**	-1.10**	-0.80*
	(0.44)	(0.46)	(0.44)	(0.43)	(0.45)	(0.44)	(0.47)	(0.37)	(0.40)
Female	0.89***	0.94***	0.93***	0.78***	0.98***	0.84***	1.02***	0.93***	0.78**
	(0.17)	(0.19)	(0.21)	(0.22)	(0.19)	(0.17)	(0.21)	(0.23)	(0.25)
Race/ethnicity (ref. White)									
Black	-1.31**	-0.97*	-1.13**	-1.00+	-0.97*	-1.06*	-0.98*	-1.03*	-1.22**
	(0.45)	(0.42)	-0.44	(0.52)	(0.43)	(0.45)	(0.41)	(0.42)	(0.46)
Hispanic	-1.21+	-0.77	-0.78	-0.64	-0.76	-0.74	-0.78	-0.73	-0.64
	(0.72)	(0.72)	(0.70)	(0.79)	(0.73)	(0.68)	(0.70)	(0.74)	(0.73)
Other	-0.29	-0.16	-0.17	-0.20	-0.12	-0.30	-0.12	-0.16	-0.33
	(0.56)	(0.56)	(0.51)	(0.56)	(0.56)	(0.48)	(0.53)	(0.55)	(0.46)
Age	-0.03	-0.02	0.00	-0.00	-0.01	-0.05	-0.02	-0.02	-0.02
	(0.10)	(0.09)	(0.09)	(0.10)	(0.09)	(0.08)	(0.09)	(0.09)	(0.11)
Adolescent PVT score		0.09***	0.09***	0.08***	0.09***	0.08***	0.09***	0.08***	0.07***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Adolescent cognitive deficit		-1.98***	-1.83***	-1.64***	-1.93***	-2.86***	-1.98***	-1.28*	-1.92*
		(0.32)	(0.41)	(0.45)	(0.31)	(0.38)	(0.34)	(0.65)	(0.92)
Select neighborhood for schools		0.26	0.23	0.25	0.26	0.28	0.29	0.36	0.29
		(0.23)	(0.27)	(0.21)	(0.23)	(0.26)	(0.25)	(0.28)	(0.31)
Conscientiousness		0.29	0.25	0.22	0.25	0.14	0.16	0.25	0.05
		(0.32)	(0.30)	(0.32)	(0.33)	(0.31)	(0.32)	(0.30)	(0.29)
School connectedness			-0.17						-0.17
			(0.19)						(0.18)
Parent support			0.06						0.01
			(0.06)						(0.05)
Teacher support			-0.42+						-0.46+
			(0.22)						(0.26)
Parent expect HS graduate			0.09						-0.04
			(0.23)						(0.20)
Parent expect college			0.30						0.26
			(0.19)						(0.19)
Neighborhood connectedness			0.12						0.14
			(0.12)						(0.11)
School strain			-0.16						0.05
			(0.23)						(0.19)
Grade point average (ref. C)									
D or lower				0.16					0.34
				(0.55)					(0.44)
B				0.67					0.37
				(0.41)					(0.44)
A				2.09***					1.60**

				(0.54)					(0.49)
Adolescent self esteem					-0.01				-0.13
					(0.16)				(0.17)
Adolescent depressive symptoms					-0.05				-0.05
					(0.06)				(0.06)
Educational attainment (ref. HS)									
Less than HS						0.22			0.52
						(1.30)			(1.23)
Some college						0.85+			0.81*
						(0.43)			(0.40)
College or more						1.92***			1.49**
						(0.47)			(0.57)
Household income						0.11+			0.09
						(0.06)			(0.06)
Adult depressive symptoms							-0.06		-0.04
							(0.05)		(0.06)
Perceived stress scale							-0.17		-0.11
							(0.29)		(0.27)
Current cigarette smoker								-1.12*	-0.68+
								(0.47)	(0.39)
Alcohol consumption								0.11	0.06
								(0.11)	(0.12)
Physical activity								-0.03	-0.04
								(0.04)	(0.04)
Cardiometabolic risk								-0.49*	-0.39+
								(0.25)	(0.21)
RANDOM EFFECTS									
Variance Components									
School	-0.74*	-1.22*	-1.35+	-0.90*	-1.25*	-1.25+	-1.55	-1.09*	-0.96+
	(0.34)	(0.57)	(0.73)	(0.36)	(0.62)	(0.72)	(1.01)	(0.48)	(0.50)
Individual	1.38***	1.35***	1.34***	1.33***	1.35***	1.33***	1.35***	1.34***	1.31***
	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)	(0.04)

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

APPENDIX 2-2. ASSOCIATION OF HOUSEHOLD INCOME WITH MEMORY FUNCTION AMONG THOSE FROM AFFLUENT NEIGHBORHOODS (N=2,142)

	Baseline	Selection Processes	Adolescent Resources	Academic Performance	Adolescent Mental Health	Status Attainment	Adult Mental Health	Adult Health Behaviors	Full Model
FIXED EFFECTS									
Intercept	16.20***	7.39*	7.34*	7.59*	8.70*	6.98*	8.67**	7.94**	10.64***
	(3.13)	(3.17)	(3.22)	(3.09)	(3.46)	(3.17)	(2.98)	(2.93)	(3.20)
Low adolescent household income	-1.61***	-1.11*	-1.11*	-0.97*	-1.09*	-0.74	-1.01*	-0.94*	-0.65
	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.46)	(0.47)
Female	0.88***	0.99***	0.95***	0.84***	1.00***	0.83***	1.08***	1.01***	0.82***
	(0.21)	(0.22)	(0.24)	(0.22)	(0.22)	(0.23)	(0.22)	(0.24)	(0.24)
Race/ethnicity (ref. White)									
Black	-1.52**	-0.95*	-0.99*	-0.95*	-0.91+	-0.98*	-0.90+	-1.03*	-0.97*
	(0.49)	(0.48)	(0.49)	(0.47)	(0.48)	(0.48)	(0.49)	(0.47)	(0.49)
Hispanic	-1.20*	-0.88*	-0.89*	-0.85*	-0.83*	-0.82+	-0.88*	-0.93*	-0.86*
	(0.49)	(0.42)	(0.42)	(0.43)	(0.42)	(0.45)	(0.40)	(0.44)	(0.44)
Other	-0.58	-0.41	-0.49	-0.45	-0.37	-0.38	-0.39	-0.36	-0.45
	(0.39)	(0.39)	(0.36)	(0.38)	(0.39)	(0.35)	(0.38)	(0.36)	(0.32)
Age	0.03	0.05	0.06	0.06	0.07	0.05	0.04	0.06	0.05
	(0.11)	(0.10)	(0.10)	(0.10)	(0.10)	(0.09)	(0.10)	(0.09)	(0.09)
Adolescent PVT score		0.08***	0.08***	0.07***	0.07***	0.07***	0.07***	0.07***	0.06***
		(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Adolescent cognitive deficit		-4.59*	-4.79*	-3.95*	-4.50*	-4.39***	-4.04*	-4.04+	-3.44***
		(2.01)	(2.05)	(1.66)	(1.98)	(1.18)	(1.64)	(2.14)	(1.00)
Select neighborhood for schools		-0.04	-0.07	-0.07	-0.07	-0.07	-0.07	-0.00	-0.13
		(0.22)	(0.23)	(0.22)	(0.23)	(0.23)	(0.23)	(0.21)	(0.24)
Conscientiousness		-0.00	-0.02	-0.01	-0.02	-0.08	-0.10	-0.06	-0.13
		(0.18)	(0.18)	(0.18)	(0.18)	(0.18)	(0.19)	(0.18)	(0.18)
School connectedness			0.08						0.05
			(0.13)						(0.14)
Parent support			-0.02						-0.04
			(0.04)						(0.05)
Teacher support			0.01						-0.04
			(0.27)						(0.26)
Parent expect HS graduate			0.01						-0.04
			(0.17)						(0.17)
Parent expect college			0.12						0.01
			(0.16)						(0.16)
Neighborhood connectedness			-0.06						-0.07
			(0.08)						(0.09)
School strain			-0.17						-0.02
			(0.14)						(0.13)
Grade point average (ref. C)									
D or lower				-0.93**					-0.46
				(0.32)					(0.35)
B				0.86**					0.55+
				(0.28)					(0.30)
A				0.99*					0.45
				(0.44)					(0.44)

Adolescent self esteem					-0.15				-0.18
					(0.12)				(0.13)
Adolescent depressive symptoms					-0.08*				-0.05
					(0.04)				(0.04)
Educational attainment (ref. HS)									
Less than HS						-0.49			-0.28
						(0.80)			(0.83)
Some college						0.99*			0.81+
						(0.47)			(0.47)
College or more						1.98**			1.49*
						(0.65)			(0.66)
Household income						0.08			0.07
						(0.06)			(0.06)
Adult depressive symptoms							-0.09*		-0.07+
							(0.04)		(0.04)
Perceived stress scale							-0.03		0.05
							(0.23)		(0.23)
Current cigarette smoker								-1.15***	-0.61*
								(0.30)	(0.31)
Alcohol consumption								0.14*	0.11+
								(0.06)	(0.06)
Physical activity								0.00	-0.01
								(0.03)	(0.03)
Cardiometabolic risk								-0.26	-0.16
								(0.26)	(0.27)
RANDOM EFFECTS									
Variance Components									
School	0.03	-0.27	-0.30+	-0.29+	-0.28	-0.40*	-0.27	-0.36+	-0.39+
	(0.15)	(0.17)	(0.18)	(0.17)	(0.18)	(0.19)	(0.18)	(0.19)	(0.20)
Individual	1.40***	1.38***	1.37***	1.37***	1.37***	1.36***	1.37***	1.37***	1.35***
	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

APPENDIX 4-1. COHORT DIFFERENCES IN THE ASSOCIATION OF LIFE COURSE SOCIOECONOMIC DISADVANTAGE WITH COGNITIVE DECLINE, UNWEIGHTED (N=23,456)

Fixed Effects Parameters						
For the Intercept						
Intercept	23.544***	21.487***	22.282***	22.755***	21.964***	19.408***
	(0.086)	(0.482)	(0.489)	(0.470)	(0.491)	(0.534)
Cohort		0.488***	0.406***	0.371***	0.550***	0.561***
		(0.097)	(0.097)	(0.094)	(0.099)	(0.099)
Low parent education			-1.583***	-0.725***	0.655+	0.658+
			(0.124)	(0.122)	(0.376)	(0.376)
Low childhood SES			-0.120	-0.167	0.208	0.205
			(0.188)	(0.178)	(0.607)	(0.606)
Father unemployment			-0.275*	-0.216+	0.663+	0.630+
			(0.136)	(0.129)	(0.378)	(0.378)
Low respondent education				-3.504***	-2.908***	-2.862***
				(0.154)	(0.423)	(0.423)
Low household income				-1.408***	-0.909*	-0.957*
				(0.121)	(0.380)	(0.381)
Low household assets				-0.643***	0.337	0.257
				(0.112)	(0.409)	(0.409)
Low parent education X Cohort					-0.305***	-0.306***
					(0.079)	(0.079)
Low childhood SES X Cohort					-0.079	-0.077
					(0.123)	(0.123)
Father unemployment X Cohort					-0.192*	-0.176*
					(0.079)	(0.079)
Low respondent education X Cohort					-0.142	-0.140
					(0.089)	(0.089)
Low household income X Cohort					-0.105	-0.099
					(0.074)	(0.075)
Low household assets X Cohort					-0.200*	-0.184*
					(0.081)	(0.081)
For the Linear Growth Rate						

Intercept	0.261***	0.568***	0.620***	0.597***	0.571***	0.574***
	(0.008)	(0.030)	(0.031)	(0.029)	(0.030)	(0.030)
Cohort		-0.074***	-0.084***	-0.080***	-0.071***	-0.074***
		(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
Low parent education			-0.011	-0.005	-0.026**	-0.026**
			(0.007)	(0.007)	(0.009)	(0.009)
Low childhood SES			0.028**	0.014	0.008	0.008
			(0.011)	(0.010)	(0.015)	(0.015)
Father unemployment			0.010	0.012+	-0.004	-0.003
			(0.007)	(0.007)	(0.009)	(0.009)
Low respondent education				-0.009	-0.020+	-0.019+
				(0.007)	(0.010)	(0.010)
Low household income				0.032***	0.022*	0.022*
				(0.005)	(0.009)	(0.009)
Low household assets				-0.022***	-0.042***	-0.040***
				(0.005)	(0.009)	(0.009)
For the Quadratic Growth Rate						
Intercept	-0.014***	-0.018***	-0.018***	-0.018***	-0.017***	-0.017***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Control Variables						
Female	0.938***	0.863***	0.947***	1.031***	1.021***	1.049***
	(0.066)	(0.065)	(0.064)	(0.060)	(0.060)	(0.061)
Race (ref. White)						
Black	-3.796***	-3.669***	-3.339***	-2.572***	-2.566***	-2.639***
	(0.093)	(0.093)	(0.093)	(0.088)	(0.088)	(0.088)
Other	-3.186***	-3.080***	-2.604***	-1.704***	-1.644***	-1.596***
	(0.142)	(0.142)	(0.142)	(0.132)	(0.133)	(0.133)
Died	-1.458***	-2.462***	-2.345***	-1.847***	-1.873***	-1.816***
	(0.086)	(0.094)	(0.093)	(0.087)	(0.087)	(0.087)
Nonresponse	-0.562***	-0.546***	-0.512***	-0.446***	-0.450***	-0.445***
	(0.092)	(0.091)	(0.090)	(0.083)	(0.083)	(0.083)

Childhood SRH						0.324***
						(0.033)
BMI						0.039***
						(0.005)
Current smoker						0.131+
						(0.071)
Married						-0.089+
						(0.053)
Retired						0.159***
						(0.043)
Random Effects (Variance Components)						
Level 1: Within-person	1.241***	1.237***	1.239***	1.245***	1.245***	1.244***
Level 2: In intercept	-1.355***	-1.342***	-1.350***	-1.407***	-1.408***	-1.414***
Level 2: In growth rate	-0.748***	-0.793***	-0.795***	-0.841***	-0.838***	-0.833***
Number of observations	76,879	76,879	76,879	76,879	76,879	76,879

Standard errors in parentheses
*** $p<0.001$, ** $p<0.01$, * $p<0.05$, + $p<0.1$

APPENDIX 4-2. COHORT DIFFERENCES IN THE ASSOCIATION OF LIFE COURSE SOCIOECONOMIC DISADVANTAGE WITH COGNITIVE DECLINE, END WEIGHTS (N=23,456)

Fixed Effects Parameters						
For the Intercept						
Intercept	24.379***	24.933***	25.934***	26.429***	26.094***	24.463***
	(0.080)	(0.506)	(0.512)	(0.495)	(0.516)	(0.569)
Cohort		-0.097	-0.234*	-0.273**	-0.201+	-0.202*
		(0.102)	(0.102)	(0.099)	(0.103)	(0.103)
Low parent education			-1.491***	-0.758***	-0.227	-0.209
			(0.127)	(0.124)	(0.430)	(0.430)
Low childhood SES			0.054	0.023	-0.213	-0.225
			(0.183)	(0.181)	(0.730)	(0.732)
Father unemployment			-0.371**	-0.300*	0.063	0.079
			(0.143)	(0.138)	(0.472)	(0.470)
Low respondent education				-3.281***	-2.446***	-2.327***
				(0.208)	(0.582)	(0.582)
Low household income				-1.480***	-0.707	-0.776
				(0.161)	(0.509)	(0.511)
Low household assets				-0.794***	-0.402	-0.477
				(0.132)	(0.536)	(0.535)
Low parent education X Cohort					-0.115	-0.113
					(0.091)	(0.091)
Low childhood SES X Cohort					0.050	0.054
					(0.149)	(0.149)
Father unemployment X Cohort					-0.077	-0.065
					(0.097)	(0.096)
Low respondent education X Cohort					-0.191	-0.192
					(0.124)	(0.124)
Low household income X Cohort					-0.158	-0.143
					(0.102)	(0.102)
Low household assets X Cohort					-0.079	-0.055
					(0.106)	(0.106)

For the Linear Growth Rate						
Intercept	0.116***	0.160***	0.203***	0.206***	0.188***	0.192***
	(0.008)	(0.033)	(0.034)	(0.033)	(0.034)	(0.034)
Cohort		-0.018***	-0.026***	-0.027***	-0.022***	-0.023***
		(0.005)	(0.005)	(0.005)	(0.006)	(0.005)
Low parent education			-0.011	-0.002	-0.009	-0.010
			(0.007)	(0.007)	(0.010)	(0.010)
Low childhood SES			0.018+	0.006	0.010	0.010
			(0.011)	(0.010)	(0.018)	(0.018)
Father unemployment			0.011	0.013+	0.007	0.007
			(0.007)	(0.007)	(0.011)	(0.011)
Low respondent education				-0.027**	-0.042**	-0.043**
				(0.009)	(0.014)	(0.014)
Low household income				0.039***	0.023*	0.023*
				(0.006)	(0.012)	(0.012)
Low household assets				0.001	-0.007	-0.007
				(0.006)	(0.012)	(0.012)
For the Quadratic Growth Rate						
Intercept	-0.010***	-0.010***	-0.011***	-0.011***	-0.010***	-0.010***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Control Variables						
Female	0.986***	0.961***	1.018***	1.047***	1.041***	1.024***
	(0.071)	(0.071)	(0.070)	(0.066)	(0.066)	(0.067)
Race (ref. White)						
Black	-3.874***	-3.813***	-3.482***	-2.699***	-2.692***	-2.725***
	(0.121)	(0.122)	(0.123)	(0.113)	(0.113)	(0.114)
Other	-2.909***	-2.825***	-2.402***	-1.649***	-1.613***	-1.584***
	(0.176)	(0.177)	(0.172)	(0.159)	(0.161)	(0.162)
Died						
Nonresponse						

Childhood SRH						0.345***
						(0.039)
BMI						0.011*
						(0.005)
Current smoker						-0.324***
						(0.083)
Married						-0.217***
						(0.061)
Retired						0.010
						(0.051)
Random Effects (Variance Components)						
Level 1: Within-person	1.164***	1.162***	1.163***	1.167***	1.167***	1.167***
Level 2: ln intercept	-1.697***	-1.689***	-1.696***	-1.748***	-1.748***	-1.756***
Level 2: ln growth rate	-0.407***	-0.415***	-0.421***	-0.474***	-0.473***	-0.466***
Number of observations	76,879	76,879	76,879	76,879	76,879	76,879

Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1

APPENDIX 4-3. STRATIFIED GROWTH CURVE MODELS BY COHORT

	AHEAD	CODA	HRS	WB	BB
Fixed Effects					
For the Intercept					
Intercept	10.453*	16.273***	23.551***	26.602***	25.706***
	(4.136)	(1.167)	(0.615)	(0.212)	(0.176)
Low parent education	-3.816	0.173	-0.707*	-0.807**	-1.066***
	(3.750)	(0.637)	(0.333)	(0.250)	(0.270)
Low perceived childhood SES	-2.827	0.250	-0.788	0.293	-0.288
	(1.733)	(1.035)	(0.636)	(0.383)	(0.371)
Father unemployment	0.187	-0.472	0.348	-0.577+	-0.113
	(1.074)	(0.662)	(0.399)	(0.304)	(0.283)
Low respondent education	-3.297**	-0.984	-3.832***	-3.773***	-2.814***
	(1.053)	(0.778)	(0.460)	(0.469)	(0.467)
Low household income	-1.628*	-0.976	-0.637	-1.216**	-1.377***
	(0.740)	(0.615)	(0.450)	(0.430)	(0.377)
Low household assets	-0.830	-0.869	-0.402	-0.461	-0.957***
	(0.872)	(0.738)	(0.444)	(0.310)	(0.261)
For the Linear Growth Rate					
Intercept	1.493***	0.935***	0.335***	-0.168***	-0.091
	(0.160)	(0.086)	(0.058)	(0.050)	(0.069)
Low parent education	0.090	-0.018	-0.007	0.009	0.077
	(0.111)	(0.027)	(0.017)	(0.018)	(0.062)
Low perceived childhood SES	0.078	0.038	0.051	-0.003	0.081
	(0.054)	(0.044)	(0.032)	(0.031)	(0.088)
Father unemployment	-0.000	0.027	-0.015	0.012	-0.033
	(0.035)	(0.028)	(0.020)	(0.020)	(0.067)
Low respondent education	0.008	-0.090**	-0.005	-0.037	-0.085
	(0.033)	(0.032)	(0.023)	(0.030)	(0.100)
Low household income	0.035	0.023	0.007	0.026	-0.078
	(0.022)	(0.023)	(0.022)	(0.031)	(0.081)
Low household assets	-0.004	-0.002	-0.019	-0.028	0.020
	(0.025)	(0.029)	(0.022)	(0.025)	(0.062)

For the Quadratic Growth Rate					
Intercept	-0.035***	-0.027***	-0.015***	0.002	-0.009
	(0.002)	(0.002)	(0.001)	(0.002)	(0.008)
Controls					
Female	0.622**	1.136***	1.203***	1.027***	0.501***
	(0.200)	(0.164)	(0.110)	(0.168)	(0.116)
Race (ref. White)					
Black	-3.654***	-3.453***	-2.690***	-2.691***	-2.099***
	(0.347)	(0.408)	(0.186)	(0.323)	(0.175)
Other	-2.602**	-2.621***	-1.302***	-2.128***	-1.306***
	(0.978)	(0.506)	(0.317)	(0.473)	(0.205)
Death	-1.877***	-1.949***	-2.136***	-1.257***	-0.360
	(0.199)	(0.181)	(0.187)	(0.375)	(0.472)
Nonresponse	-0.730*	-0.527*	-0.694***	-0.770***	-0.101
	(0.285)	(0.209)	(0.153)	(0.223)	(0.200)
Random Effects (Variance Components)					
Level 1: Within-person	1.290***	1.188***	1.091***	1.140***	1.113***
Level 2: In intercept	2.886***	2.415***	2.051***	0.983***	0.921***
Level 2: In growth rate	-0.494***	-0.696***	-0.936***	-2.249***	-0.583***
Observations	17,014	16,386	30,955	5,782	7,185
Number of groups	4,391	2,990	6,655	2,670	7,013

Robust standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1